METAL PROGRESS

NOVEMBER, 1941 VOLUME 40, NO. 5

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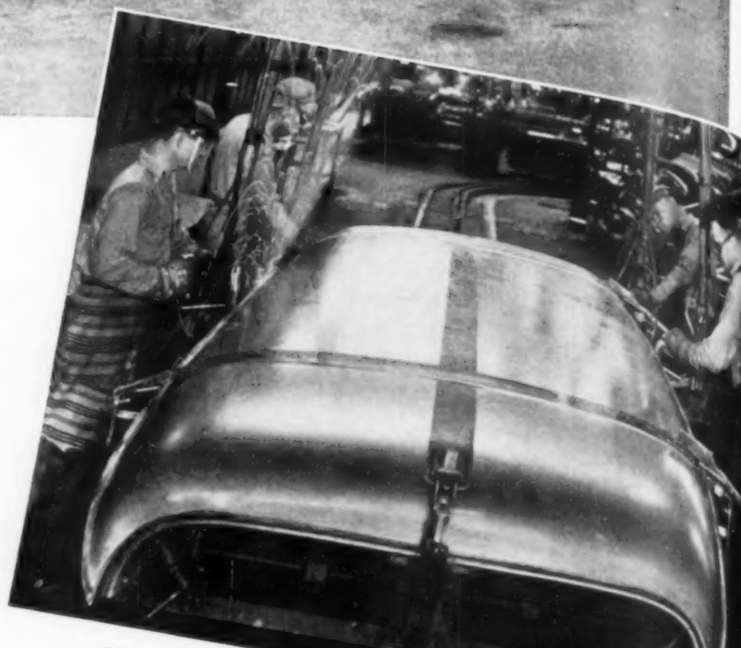
The cover is adapted from a photograph kindly supplied by Ford Motor Co. (See page 766 for credit for October's cover.)

Metal Progress Is Owned and Published by
THE AMERICAN SOCIETY FOR METALS

Refugee kiddies inspect a new ambulance presented by the British-American Ambulance Corps.



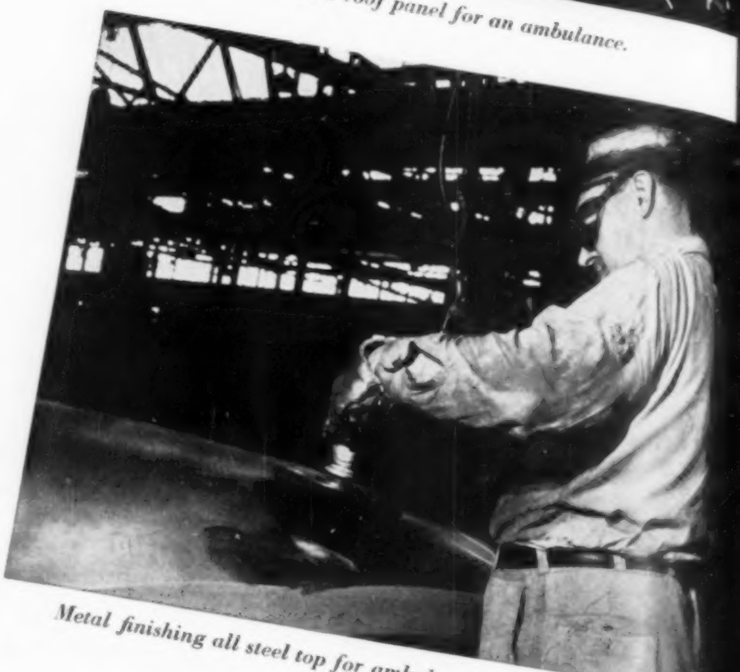
Gun welding an all steel roof panel for an ambulance.

Some
Inland Defense Steel
Goes on
Errands of Mercy

Every day Inland ships thousands of tons of steel for the Defense Program. A large part of the tonnage is used for constructing new plants, building equipment, and manufacturing munitions. However, some Inland Defense Steel goes on errands of mercy. Typical of this are the Inland Sheets used by automobile manufacturers in building ambulances for service not only in our own army camps, but also in the camps and among the civilian populations over seas.

Inland has always been proud of its ability to serve customers well through a closely knit organization, complete control of raw materials and modern plants. And now—because defense is Inland's No. 1 Job, all Inland men and all Inland facilities are coordinated in serving our Government to the fullest extent possible in the present emergency.

SHEETS · STRIP · TIN PLATE · BARS · PLATES
FLOOR PLATE · STRUCTURALS · PILING · RAILS
TRACK ACCESSORIES · REINFORCING BARS



Metal finishing all steel top for ambulance body.

INLAND STEEL CO.

38 S. Dearborn Street, Chicago • Sales Offices: Milwaukee, Detroit, St. Paul, St. Louis, Kansas City, Cincinnati, New York

At a meeting of the National Academy of Sciences in Madison, Wis., last month, Dr. Jeffries outlined the way in which that organization was acting in a consulting capacity to the Office of Production Management. Since he heads up such work relating to the conservation of metals and substitutions for the least available ones, his conclusions concerning the adequacy of our visible supplies of metals for the national defense program are worthy of close attention. Seemingly, men closest to production are the least worried.

SUPPLY OF METALS FOR NATIONAL DEFENSE

By ZAY JEFFRIES
Technical Director, Lamp Department, General Electric Co., Cleveland, Ohio

WHEN, near the middle of 1940, the Advisory Commission to the Council of National Defense was established, it was only natural that great stress was put on the importance of metals and minerals, and equally natural that Dr. CHARLES KENNETH LEITH* should find himself in the center of this activity. Dr. LEITH has made a profound study of the relationships between minerals and war. He has served the government, directly and indirectly, for more than a quarter of a century, and for the past twenty years has advocated the stockpiles of such minerals as are not obtainable or of which there is a deficiency in the Western Hemisphere. He has eloquently pointed out that the nations controlling the great mineral deposits of the world should lead in both industrial and war strength; that no continent is self-sufficient in all the minerals necessary for either a complete industrial development or the most efficient prosecution of war; that the mineral distribution is such that no continent can obtain all the necessary minerals without sea transportation; and hence that the value of sea control can hardly be overestimated.

*The eminent professor of geology at the University of Wisconsin and member of the National Academy of Sciences, whose work has done so much to clarify the origin of the Lake Superior iron ore deposits.

Dr. LEITH early called on the National Academy of Sciences for technologic help on manganese and tin. By February, 1941, the problems were multiplying to such an extent that he asked the Academy to arrange for a comprehensive organization to provide the Office of Production Management, successor to the Advisory Commission to the Council of National Defense, with advice on metals and minerals.

FRANK B. JEWETT, President of the National Academy of Sciences, created such an organization known as "The Advisory Committee on Metals and Minerals of the National Academy of Sciences and the National Research Council". CLYDE WILLIAMS, head of Battelle Memorial Institute, is Chairman — and a most able one. The Committee has been subdivided into four main groups, as follows:

Ferrous Minerals and Ferro-Alloys Group
Chairman: GILBERT E. SEIL; 11 members
Non-Metallic Minerals Group
Chairman: R. P. HEUER; 12 members
Tin Smelting and Reclamation Group
Chairman: F. W. WILLARD; 6 members
Metals Conservation and Substitution Group
Chairman: ZAY JEFFRIES; 27 members

Problems on which advice is sought originate in O.P.M. and clear through Dr. LEITH to

Where Does All the Metal Go? 27,000 tons of structural steel alone went into a mile-long assembly building at Fort Worth, Texas, for bombers. Photo courtesy The Austin Co., engineers and builders

Mr. WILLIAMS who makes the specific assignments to the proper group. In the preparation of reports, help is sought from the most authoritative sources including individuals, universities, companies, government agencies and bureaus and independent laboratories. All these groups have cooperated splendidly; they not only have given of their time and energy but have literally opened the archives of their confidential information. I hope that after this terrible international storm has passed there will be given adequate recognition of such service.

Some of the committee reports are confidential, some are confidential in part, and others are available for release to interested parties.† In the short time allowed for this presentation, only a few high spots can be covered. Being more familiar with the group of which I am chairman, I shall confine my remaining remarks to the work of the Metals Group. Any opinions offered in the following notes are personal.

Before the complete organization of the Metals Group on March 15, 1941, we had responded to an urgent request from Dr. LEITH for a report on the nickel situation. A shortage was not only impending, it was at hand. To date, 23 other formal reports have been submitted. Still other reports are being prepared and no end of problems seems in sight while the emergency lasts.

To gain some idea of the scope of the studies, it may suffice to name the metals on which formal reports have been or are being made. These include nickel, aluminum, magnesium, zinc, chromium, manganese, vanadium, tungsten, molybdenum, copper, tin, antimony, cadmium, lead, cobalt, mercury, iridium, ruthenium, low-alloy structural steels, die castings, and steel and cast iron rolls. Other reports cover specific processes relating to one or more of these metals.

SITUATIONS SHIFT RAPIDLY

The O.P.M. has specialists on each of the major metals and our committee cooperates closely with them. The metal pictures change so rapidly that it is necessary to contact these specialists at intervals to avoid working on obsolete phases of the metal problems. By working on the right problems our group helps O.P.M. to a better understanding of the metal requirements for both defense and non-defense and,

†Some have been released to the press — for instance, the one on chromium reprinted on page 676 of October's METAL PROGRESS.

it is hoped, toward a wiser administration of the metal allocations.

The steps taken to ease the nickel shortage by substitutions put an added burden on other metals such as chromium, copper and vanadium. A threatened aluminum shortage put a heavier load on copper and zinc, among other metals, and a zinc shortage still further strained the copper supply. A shortage in one metal tends to eat into the stocks of other metals.

Because the steel production is ten times that of all other metals combined, it has taken much of the substitution load and, in the end, it must provide the lion's share of any substantial increase in metal consumption. Even now, steel is scarce. A few months ago it seemed as if lead would be plentiful. Unavailability of such metals as copper, zinc and aluminum in sufficient quantities to meet the large non-defense demands has finally resulted in an acute lead shortage.

Thus the story of the past six months has been one of a succession of metal shortages encompassing all the major metals. Of the important defense metals, the supply of molybdenum alone seems to be ample. However, if the emergency lasts a year or two longer we may look for a shortage of this metal.

To make the situation worse, there is the criticism that our stockpiles of essential metals are too low. This is true, but the critics are displaying hindsight wisdom. Large stockpiles of strategic metals cannot be built up during a world war. The substantial accumulations must be made in peace-time, and authorizations were not adequate until it was too late.

Are things actually as bad as this recitation sounds? Are the shortages real? Is there a ray of light ahead? Surely we do not want to be complacent in the midst of a program calling for every constructive effort; but neither should we become hysterical and lose our sense of proportion. In pointing out some of the brighter facets I shall try to steer the middle course between complacency and hysteria.

Unprecedented Metallurgical Supplies

First, the shortages are not caused by a lower supply, but by a greatly increased demand. The supplies of the various metals are the greatest in history. Some of the minor metals are available in amounts exceeding twice the normal consumption. Even our steel production is 25% above that for a reasonably good peace-time year. However, for the past 12 months the people of the United States have been on a buying spree. Fear of shortage and fear of higher prices both induce buying for future use. The extent of purchases beyond immediate needs is unknown, but, judging from spot checks, this must have been an important factor in the large demand.

When it is realized, however, that this tremendous non-defense use of metals has been concurrent with a major program of building and equipping defense plants, the wonder is

Personnel of Metals Conservation and Substitution Group

Robert S. Archer
Republic Steel Corp.

E. W. Bennett
Dow Chemical Co.

A. L. Boegehold
General Motors Corp.

S. K. Colby
Aluminum Co. of America

D. K. Crampton
Chase Brass & Copper Co.

W. H. Eisenman, *Secretary*
American Society for Metals

Maj. L. S. Fletcher
Frankford Arsenal

John R. Freeman, Jr.
American Brass Co.

James P. Gill
Vanadium-Alloys Steel Co.

H. W. Gillett
Battelle Memorial Institute

W. C. Hamilton
American Steel Foundries

Charles H. Herty, Jr.
Bethlehem Steel Co.

Zay Jeffries, *Chairman*
General Electric Co.

John Johnston
U. S. Steel Corp.
Research Laboratories

A. B. Kinzel
Union Carbide & Carbon Corp.

Robert H. Leach
Handy & Harman

Robert F. Mehl
Carnegie Institute of Technology

Paul D. Merica, *Vice-Chairman*
International Nickel Co.

W. M. Peirce
New Jersey Zinc Co.

Albert J. Phillips
American Smelting & Refining Co.

William B. Price
Scovill Mfg. Co.

H. S. Rawdon
National Bureau of Standards

Lt. Col. S. B. Ritchie
Watertown Arsenal

Walter C. Smith
Cerro de Pasco Copper Co.

Jerome Strauss
Vanadium Corp. of America

F. W. Willard
Nassau Smelting & Refining Co.

W. P. Woodside
Climax Molybdenum Co.

not that shortages appeared but that it was possible to provide metals for both activities. As the defense plants are brought into production they will naturally require a larger percentage of the metals, but they will also need a larger percentage of the labor, transportation, electrical energy and many services, thus tending to lessen dislocation resulting from the curtailment of the use of metals in non-defense industries.

Another favorable factor is the quality of the available alloys. The supply of steel alloying elements such as nickel, chromium, molybdenum, vanadium, and even manganese, is so much greater than normal that a larger percentage of alloy steel is being made than ever before. The enhanced quality of the alloy steels not only makes possible more war material from a given tonnage, but it will make our munitions, all along the line, superior to those of the Axis powers. So, to the greatest metal quantity of all time, we can add the highest average quality of all time.

Now, a few words about the stockpiles. Notwithstanding the late start and the war conditions, stocks of some of the most strategic metals have been accumulated. While these stocks are not nearly as large as desired, they are large enough to cushion any sudden blow, and they have been built under most trying circumstances. Then there is additional comfort on the stockpile matter. Because we have been for years the greatest industrial nation and have consumed more metal than any other country, we have the greatest of all stores — the metals in use. Except for normal scrap recovery, we have never really drawn from this vast store of metal because we have never had the need to do so. This reservoir can be tapped to almost any extent required by the emergency. For example, if aluminum is desperately needed, 100,000,000 lb. could be drawn off in a few weeks.

Again, we have watched the succession of shortages, but have we learned anything from the experience?

Yes, we have learned much. We have found that in many places non-metals, such as plastics, glass, fabric and wood, can be substituted, at least temporarily, for metals. We have seen that, although there are places in which the use of a particular metal is well-nigh indispensable, there are sufficient uses of nearly all the metals in which a wide variety of substitutions of other metals can be made so that all the available metal can be consumed. It is concluded from this that increases in the supply of *any* metal help the whole situation. The increases can be made where expansion is easiest, cheapest or soonest. This gives assurance that steel expansion will solve many of the shortages in non-ferrous metals, at least during the emergency. This is, indeed, an important conclusion.

Time Is of the Essence

Another important factor is over-expectation on the part of the inexperienced. The American people are in the habit of expecting miracles in production. Vast numbers of automobiles, electrical appliances and the like, come streaming from the factories without seeming effort or delay. Who thinks about the long periods of research, of trial-and-error, of machine development, of process perfection, of training skilled workers, and the many other steps which necessarily preceded the production flow? In the transformation from a peace-time to a defense economy, time-consuming groundwork must also be laid. Part of it has been done, but there is still much of it left to do. Progress eventually must be rated on what comes off the production line, but at the moment it must be judged by the soundness of the preparations. They are sounder than many people think.

Let us elaborate somewhat on this. Special emphasis has been given in the press to the so-called aluminum shortage. During the five years ending with 1939, the average new aluminum consumption in the United States was 256,000,000 lb. annually. Current production is at an annual rate of around 700,000,000 lb. Obviously, there is no shortage from the standpoint of normal demand! But aluminum is the key to aircraft production, and aircraft production must be still further increased. Therefore, a further expansion in aluminum output will be necessary.

Now, one can make some new aluminum, by the thimbleful, in the laboratory in a day. But we need it in magnitudes of additional hundreds of millions of pounds. Mining operations must be expanded, great new chemical plants must be erected and equipped, new transportation facilities must be provided, new electrical machinery built, reduction and fabrication plants erected, all of which require *time*. After all these things are done, production miracles will be performed.

And so it is with much of the defense pro-

duction. The public should understand these things and, understanding, they will have greater confidence in what is being done.

Principal Need: To Tighten Our Belts

Certain other factors having a bearing on the metal problem should be mentioned:

1. Industry requires more metal during a period of expanding production than after the expansion is completed. The plant stocks must be increased both ahead of and in the production line. Industry has been expanding during the past year or more, and part of the apparent metal shortage has been used to stock up.

2. Plant inventories, in raw material, material in process and finished product, are not known. The fear complex should stimulate rather large inventories, and spot checks tend to confirm this view. In general, capacities and inventories are apt to be underestimated and requirements overestimated.

3. Much equipment, labor and material, such as in the machine-tool industry, are now being extensively used to prepare defense plants for production. When the defense plants are tooled up, these facilities will be liberated, in part, for direct defense production.

4. Plans are under way all along the line to expand the production of the primary metals. The magnitudes range from millions of tons of pig iron and steel, down to millions of pounds of mercury.

In an effort to appraise all these factors, good and bad, I venture the following opinions:

(a) There will be ample metal for the greatest defense production of all time.

(b) In addition, there will be ample metal to keep up all the essential services, including food, heat, light, transportation, communication.

(c) There will be a considerable amount of metal for civilian uses ordinarily regarded as non-essential for defense.

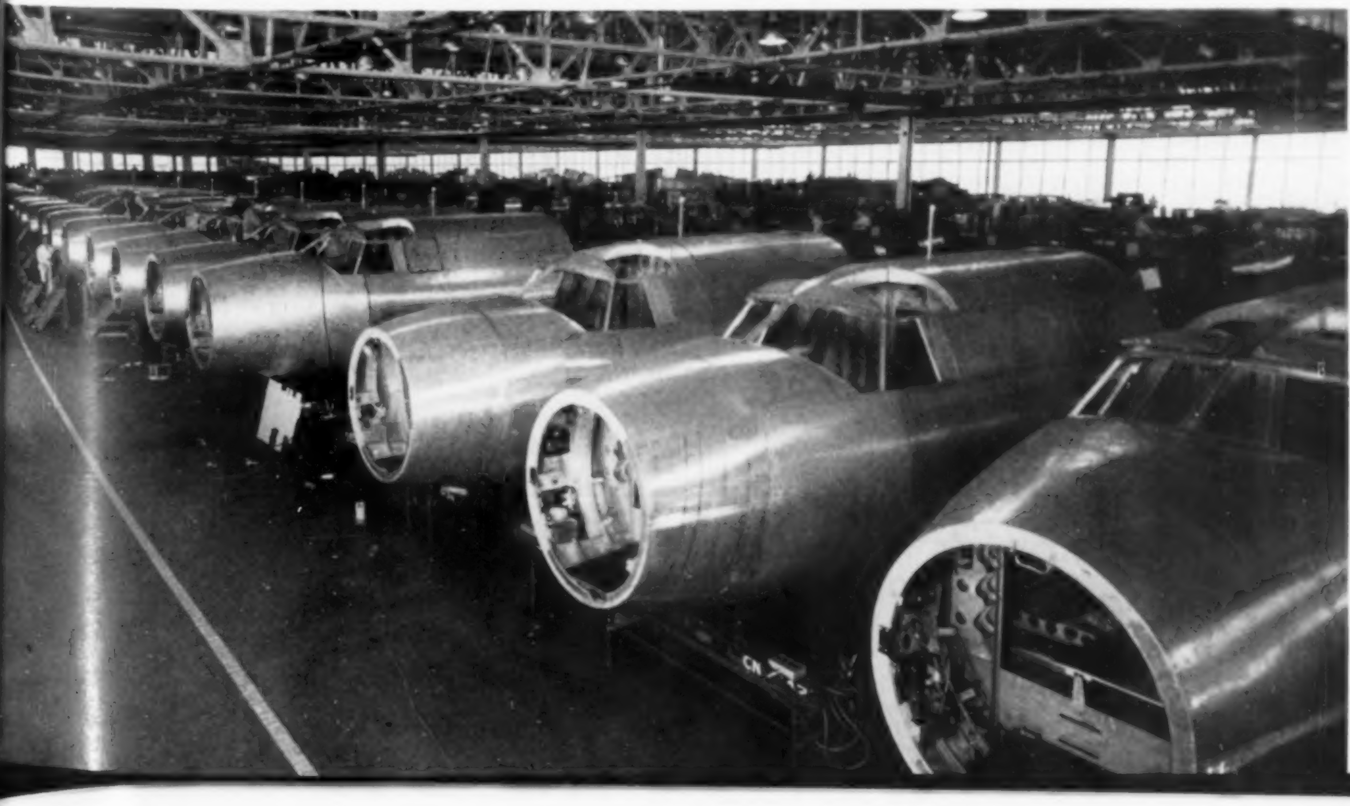
(d) The kind of metal available for many civilian uses will in many cases represent impairment, but the impaired products will serve well during the emergency.

(e) Many of the substitutions will probably have a long-range effect on many products and processes, and perhaps even on habits.

In conclusion, it may be interesting to record impressions gained from many personal contacts during the past six months and covering most phases of the metal industry. In general, the people having the least confidence in our ability to produce are those furthest from the production lines. They are the ones with little information about what is actually going on and little comprehension of what it takes to really produce. On the other hand, the men in the storm-center of production — executives, engineers, scientists, foremen and skilled workmen — have unbounded faith that our defense production will greatly surpass anything the world has ever seen.

Assuming that the latter group is the better qualified to pass judgment we are, even now, in great need of unity of purpose and action lest this vast production come too late.

30,000 Parts Make up 650 Sub-Assemblies Going Into 32 Major Assemblies for One Martin 13-Ton Medium Bomber B-26, Shown in Flight on Last Month's Cover. Here are a few nose sections in Glenn L. Martin's Baltimore plant



Launching of U.S.S. Massachusetts on Sept. 23, 1941

Hulls and superstructures of modern war ships utilize much welding to improve strength and water tightness and to reduce weight

Dav. Arnott, chief surveyor of the American Bureau of Shipping, who received the Miller Medal of the American Welding Society at the October meeting, said that half of the merchant vessels now building are all-welded. Even when making less radical designs, extensive changes in old shipyards are necessary (and are being made) to enable them to speed their launching program to today's pressing requirements. In the author's department at Quincy, Mass., are thousands of welders, burners, heaters and tack welders.

FLAME CUTTING AND ELECTRIC WELDING IN SHIPBUILDING

By CHESTER A. ROBER
Foreman, Welding and Burning Departments, Fore River Yard, Bethlehem Steel Co.

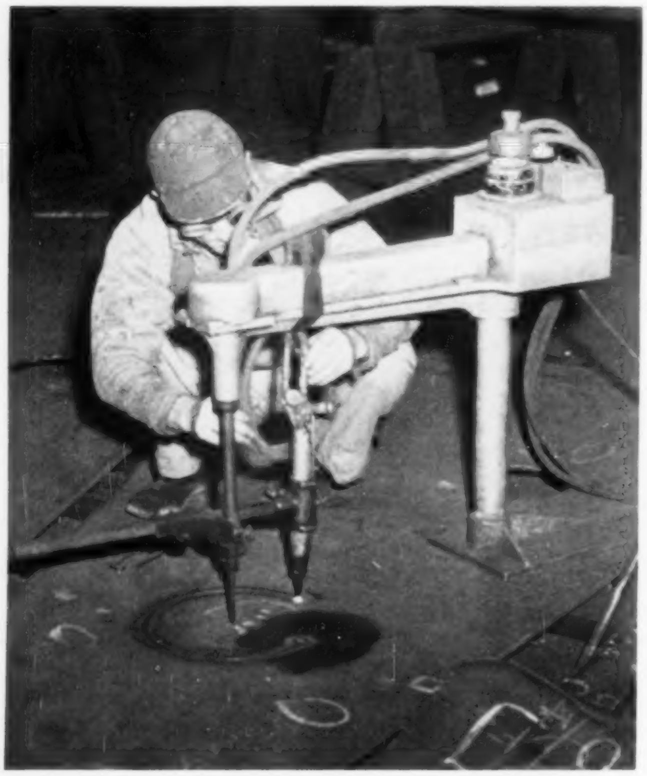
LESS than three years ago a young naval architect, in an article published in a leading marine publication, predicted that an enterprising engineer would some day design a shipbuilding yard along entirely new lines. Equipped with the latest welding and cutting appliances, this yard would be laid out for progressive welding work; long open shops and wide erection platforms would be in evidence, overhead cranes would carry fabricated units from the platforms to the shipways, where they would be welded in place. Arc welding and flame cutting would speed up production. Although at the time many skeptics ridiculed the prediction, later developments have proved it to be essentially correct, as plants under erection today have incorporated these ideas. Many old plants have also been modernized and equipped with modern welding and cutting tools, shop structures have been re-designed for welding operations, suitable platforms have been erected and crane capacities increased. With these improvements the yards are now building ships faster and more economically than ever before.

Although much has been written about general yard layout for modern construction methods, little has been said of the actual welding and cutting methods. Take for instance flame cutting, as practiced at the Fore River Yard of the Bethlehem Steel Co., Shipbuilding Division. This procedure has widened the scope of all welded steel fabrication. In fact, it has made welded fabrication practicable by providing a method for shaping parts of all sizes and contours from steel plates and slabs, at a cost within reasonable bounds. The same parts could be made by other methods, but at a cost that would be prohibitive.

FLAME CUTTING INDISPENSABLE

Several types of flame cutting equipment are in use at this plant, both hand cutting torches and machines for straight line cutting, shape cutting of various contours, and for multiple shape cutting of larger sections. Shape cutting machines are used for circular and elliptical shapes of smaller dimensions. In general, such machines now take the place of other more expensive equipment and also reduce the load on the already overtaxed machine tool industry. Hand cutting is used only on work not adaptable to machines.

Materials like shell plating requiring double and single bevel joints and all work of such nature constitute a major type of operation for cutting machines. More specialized machines



Portable Machine for Cutting Circles in Steel Plates. Scarf may be bevelled by tilting the cutting torch

are used for cutting pipe flanges and plate collars. Multiple cutting machines are used in making floors and for parts that lend themselves readily to cutting of repetitive pieces, such as access openings in inner-bottoms, floors and similar places where circular or elliptical openings are required.

Another application of oxy-acetylene gas is in the annealing of flame-cut surfaces on alloy steels of great hardenability, that subsequently must be machined or cold formed. In such cases a multiple flame torch is used for reducing the self-hardened edges to the desired range of machinable hardness.

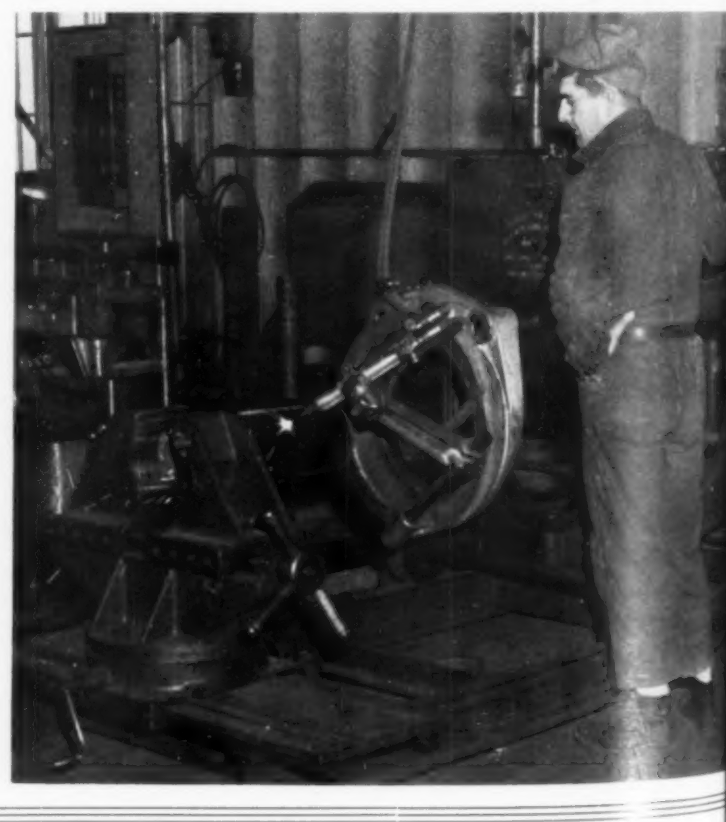
A recently developed tool now used in this yard is the flame gouging torch. As chipping or other mechanical means of removing metal are costly, this tool may be a means of reducing the cost of preparing joints for welding. It is also used to advantage in excavating castings to remove defects. The appearance of the molten cavity offers definite indications that the defect is completely removed and the cavity dug out in this way requires little further preparation for welding.

Arc Welding of Plain Steel

Practically 95% of the welding in a shipyard is done by the manual metallic arc method, a procedure noted for its flexibility. The electrodes vary in size from $\frac{3}{32}$ to $\frac{5}{16}$ in., depending on the size of plate and fillet or butt, and the size of weld required. All electrodes for Navy work are subject to approval by both U. S. Navy and the yard service. The larger sized electrodes are employed in vertical and overhead positions as rapidly as workmen can be trained in their use.

On ship work the welding positions must follow the ship lines, and about 75% of ship welding is in the vertical or overhead position. In the shops every effort is made to use positioners, shoring or rotating equipment to obtain flat position, with its greater speed and economy.

Shop assembled units requiring preheating are handled in separate enclosures in the shops and are positioned when possible. These units vary in weight from 5 to 250 tons and are usually stress relieved after welding. This type of work includes rudders, shaft struts and stern weld-



A Machine for Cutting Bevels on Pipe Automatically to Shape so the Piece Will Fit Into Another at the Intended Angle

men[illegible]. To obtain the proper preheating gradient incidental to such work electrical strip heaters are used. Temperatures are checked frequently by small contact thermocouples, and by pellets of specially selected fusible alloys the melting point of which is near the maximum temperature given in the specifications. Strip heaters have the advantage of furnishing even and easily controlled preheat.

When welding alloy steels possessing marked hardenability austenitic electrodes of the 25% Cr, 20% Ni type are used. These steels are not generally preheated, except during cool weather, when normal preheating temperatures are maintained by torches or electric strip heaters. The results of this technique have been satisfactory.

Flame Gouging. A process for removing metal around porosities and other casting defects disclosed by radiographic inspection. Arrows indicate areas excavated. Painted lines and numbers indicate areas radiographed

For austenitic types of stainless steel in the 18% Cr, 8% Ni group, the proper electrodes are used in all positions. This type of work includes deck coverings, coamings, and galleys. In the case of fire-resistant superheater supports analyzing 25% Cr and 20% Ni, an electrode of similar composition is used.

Welding Other Alloys

Many non-ferrous alloys are commonly welded in this yard, in particular manganese bronze and compositions H, M and G (88% Cu, 10% Sn, 2% Zn). This welding is really service welding and includes routine babbitting and lead burning. All such welding is centered in one shop and is carried out by men who have been given special training for this work.

A special electrode had to be developed for use in repairing defects in propellers and other manganese bronze castings, such as valve bodies, as there was no satisfactory one on the market. Rejection of bronze propellers weighing up to 10 tons, on account of comparatively small defects which could have been repaired by welding, stimulated the research work on this problem. As a result the Fore River Yard is now able to make satisfactory electric welds on manganese bronze castings, in a wide range of wall thicknesses.

Two methods are generally used for compositions G, H and M, which are somewhat similar in characteristics. These are the carbon arc and the oxy-acetylene processes. An electrode or filler rod similar to the manganese bronze electrode has been developed for these materials.

For monel (approximately 60% Ni and 40% Cu) an electrode of similar analysis is used. This work is normally done in the flat position and is confined to the sheet metal shops.

The copper-nickel alloys (particularly piping of the 70% Cu, 30% Ni type) are usually welded with a 70% Cu, 30% Ni or a 60% Ni, 40% Cu electrode, with satisfactory results.

Nickel-clad steels are used extensively in the holds of trawlers, and are welded on the nickel side with a pure nickel electrode and on the steel side with the standard medium steel electrodes.

Due to the rapid speed of deposit, aluminum welding is carried out in the shops only and by carefully trained men. For this type of work gas welding is used, although arc welding is possible and is finding wider applications.

Carbon-molybdenum steels, commonly used in high temperature applications, may be

divided into two groups: (a) Large castings subjected to gamma-ray inspection; (b) wrought materials subjected to X-ray inspection. Large castings are preheated prior to welding and tested for temperature by small hand thermocouples, because specifications will not allow a fusible alloy tell-tale in contact with this material. Parts such as this are generally arc-welded in the flat position with a heavily mineral coated electrode. Under this classification come turbine castings and valve bodies, where welding is incorporated in the design of the structure (see the photograph below).

The second group of C-Mo steels, involving chiefly high pressure piping, is welded in a separate building where mixing of the material with ordinary pipe may be avoided. These units are also preheated under careful control. Special turning jigs and tilting tables are supplied, so that a minimum of interference with continuous welding is obtained. This shop handles the fabrication, welding, heat treating, machining and X-raying of all high pressure, high temperature pipe and fittings. An accurate record of all work and inspection is kept in every case.

In the Fore River Yard three methods are commonly used for welding cast iron. Due to its difficulty each repair job is a problem in itself. However in the past few years sections of cast iron have been repaired, varying from a few pounds to many tons in weight. The three methods used are known in the shop as the hot method, the cold method, and the brazing method.

In the hot method, much consideration is given to the design of the part. Appropriate heat is applied to the section by means of large torches, and this preheating must remain constant at all times during and immediately after welding. The deposit of weld is made with an uncoated electrode at high amperage and voltage. When completed the section is reheated and blanketed with asbestos. After slow cooling, this deposit is machinable.

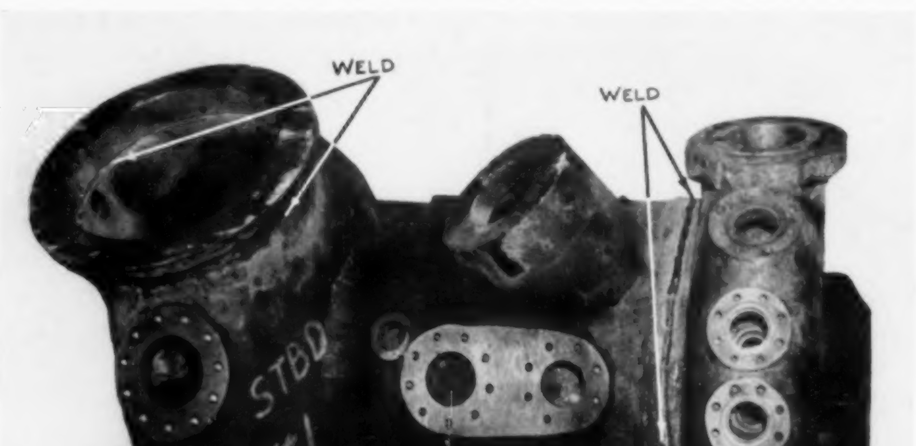
The cold method is adaptable for small repairs, not subject to pressure or tightness. An electrode of alloy composition is used. The deposit is made on the cold cast iron and may be ground to shape. Pure nickel, monel, or 5% nickel cast iron electrodes are used.

For brazing, the application is dependent on the size of the casting and the limiting amount of preheat needed for proper brazing.

Qualification of Welders

To control the quality of work a system of talent classification has been worked out so that the least experienced men are given the simplest type of work, such as mill flat work. These men are given U. S. Navy Test No. 1, which qualifies a welder to work on mild steel plate up to ¾ in. thick in all positions. After sufficient experience the man is tested on the U. S. Navy Test No. 2 for mild steel or the No. 2 special alloy test, which qualifies the welder to work on unlimited thicknesses of these materials. As the welder's ability increases still further and the need arises, he is trained and tested according to U. S. Navy specifications on various other materials such as monel, copper-nickel alloys, and stainless steel.

After gaining considerable experience on the types of work referred to above, and if the amount of work warrants, picked workmen are trained to



Turbine Casing Made of Three Steel Castings, Welded Together. In this way the foundryman may cast individual sections in the most advantageous positions

weld pipe and other pressure vessels. To qualify them for such work the U. S. Navy Test No. 4 for pressure piping is used. This is by far the hardest of all tests and is a reasonable proof that a workman has sufficient skill to perform trustworthy welding. This test supersedes all other tests on mild steels, and a man so qualified may weld work of any description on this type of material.

To avoid confusion, a list giving the qualifications of every welder is issued from time to time, and this list informs each supervisor about the general ability and qualifications of all men assigned to him. Thus a man is rarely placed on a job which he is not able to handle.

Scope of the Various Methods

Tests similar to the arc welder's tests are also required of gas welders. Except for aluminum, gas welding is confined in this yard to a few non-ferrous alloys, particularly the brasses and phosphor bronzes. As for aluminum welding, two electrodes or filler rods are common, either a silicon-aluminum rod or a pure aluminum rod. The oxy-hydrogen flame is used when gas welding aluminum.

Atomic hydrogen is used for very thin materials and where accurate heat control is essential to good welding. This process is used on thin stainless steel and aluminum sheets.

Scene in the Shop Reserved Exclusively for Work on Carbon-Molybdenum Steel Parts for High Pressure Steam Systems. Workman is welding an elbow on a straight run of pipe. Supporting rollers are power driven; the control is under operator's foot

Other methods of welding include spot and resistance welding. These methods are employed on work where thin sections are joined, such as in the manufacture of lockers.

The "Union-Melt" method of automatic arc welding is used on seams and butts of heavy sections, as in bulkheads and decks. It is not used extensively at the Fore River Yard; we find it less economical than hand welding for lighter sections and it also requires a rather extensive set-up.

Recently sections of stern frames on several of our merchant ships have been joined by thermit welding. Results have been very satisfactory, but this method is not used extensively as it is best applicable to the heaviest sections.

Today such a diversity of materials are being used in ship construction that extreme care must be taken not to apply welding incorrectly. As a point of illustration, a peculiar combination recently presented itself. Flat bars of pure nickel had to be joined together, then welded to a gun metal frame, which in turn was welded to a manganese bronze casting. This extreme case shows that the shipyard welder must be prepared not only to weld mild steels, but low and high alloy steels of various carbon content, cast irons, brasses and bronzes. Feats unheard of years ago are performed as a matter of course in the welding of metals today, and the future holds many more interesting problems in store.

To control such a variety of work the supervisor must check all materials to be welded. In some cases the type of material is plainly painted on the work, in other cases the plan must be consulted. In all cases the supervisor's office must be kept informed, and when necessary the head of the department consults with the Development Engineer or Materials Engineer and other possible sources of specialized information. Thus a workable practice can usually be evolved. However, there frequently arise conditions where no precedents exist; then the subject is turned over to a group of experienced men for consideration. Eventually the feasibility of such welding is determined.

Having the training of the workmen and the type of materials under direct control, the welding department must apply these factors to the work of building ships. The magnitude of this problem can be better understood when it is realized that a shipyard, the size of the Fore River Yard, may employ thousands of men as electric welders, burners, heaters, and tack welders, who come under the control of the welding department.

Thermit Welds in Stern Frame. Such joining methods keep the individual steel castings within practicable shipping size

Presentation of the 16th Edward deMille Campbell Memorial Lecture was interrupted not once but twice by a wave of applause — a circumstance unremembered in former occasions. Remarkable indeed are the results achieved by the electron microscope on transparent replicas of the surface conditions existing on polished and etched steel samples. Light is shed on the true action of furnace practice, deoxidation methods, and grain refiners, on the mechanism of hardening and the hardenability of our commercial steels.

THE HARDENING OF STEEL

(CAMPBELL MEMORIAL LECTURE)

By ROBERT F. MEHL

Director, Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh

THE LECTURER, in discussing the transformation of austenite (the hardening reaction in steel), pointed out that DAVENPORT and BAIN's work in 1930 which developed the "S-curves" proved with great clarity the common assumption that the formation of pearlite is a process of nucleation and growth. Since the critical cooling rate or hardenability of a simple carbon steel depends on the maximum rate at which this can occur, it seems desirable to inquire into the respective roles played by the two factors, namely the rate of formation of pearlite nuclei under a given set of conditions and the rate of subsequent growth of a grain about each nucleus.*

What I shall have to say will be chiefly an account of that which we have learned during the last few years at the Carnegie Institute of Technology concerning the formation of pearlite from this point of view. I well realize the risks that attend the presentation of new data — it would, of course, be safer to present old information newly disguised, but I should think it would be much less interesting. What is new is the result of the labors of a number of graduate students who have been working with me on this subject: Messrs. JOHNSON, HULL, SMITH, PELLISSIER, HAWKES, ROBERTS, and COLTON. I know that Professor CAMPBELL, in whose honor this lecture is given, would have understood the satisfaction I have had in associating with this group of very able students.

It should be said immediately that the characteristics of nucleation and growth processes are of wide fundamental importance, applying not only to reactions of the sort we are considering, but also to many other reactions of metallurgical importance, among which are freezing, recrystallization, and precipitation from solid solution. There is no uncertainty whatsoever concerning the mechanism; it may be readily pictured, Fig. 1, in four stages at equal time intervals. The transformation starts by the formation of nuclei, and during the course of the reaction these nuclei continue to form and, of course, those already formed to grow. These nuclei are pictured as forming at random in the untransformed matrix; the number which forms per second in a given volume of untransformed matrix is the "rate of nucleation". Each nucleus after birth begins to grow; the rate at which its radius increases with time is the "rate of growth".

The isothermal reaction curve has the shape typified by that shown in Fig. 2. This curve

*Matters in smaller type and in brackets are the EDITOR's paraphrase; otherwise Dr. MEHL's words are quoted verbatim.

represents the percentage of transformation product formed as a function of time. At first the rate of the reaction is slow, then it accelerates, reaching a maximum at about 50% transformation, and then decelerates. The initial period seems long, and it has been suggested that this period is an "incubation period" during which the matrix is preparing itself to react,

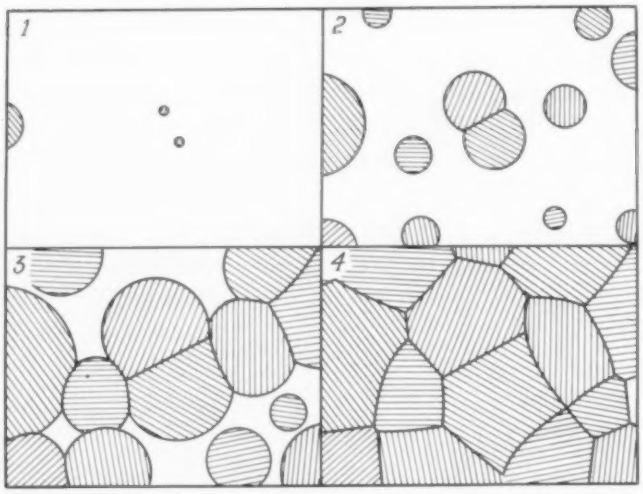


Fig. 1 — Four Stages, at Equal Time Intervals, in the Transformation of a Region by the Process of Random Nucleation at a Constant Rate and Subsequent Grain Growth, Also at a Constant Rate

but this is an unnecessary conception, for the form of the curve in the initial period is the expected one on the basis that nuclei form with time at a constant rate and grow with time at a constant rate.

[Consideration was then given to the opposite of the hardening reaction, namely the conversion of pearlite into austenite, not only to show certain differences in the controlling variables, but more especially to emphasize that the austenite is not homogeneous when first formed, and that *time* is necessary for uniform distribution of the carbon atoms in the gamma iron. There is at present no method of determining the time required to dissipate these early concentration gradients.]

We shall have much to say later concerning the important effect of carbide particles and undissipated carbon concentration gradients upon the rate of formation of pearlite and upon hardenability. At the moment it will be opportune to point out the effect which they exert upon the structure of pearlite. By preparing samples of austenite, in one case with residual undissolved carbide, and in the other case without, ROBERTS has been able to show that the isothermal reaction product at temperatures just below Ae_1 in the steel with undissolved carbide is not lamellar but resembles spheroidite formed on annealing quenched steels below Ae_1; transformed at lower temperatures the product becomes increasingly lamellar. On the other hand, the product of reaction for the steel which had been thoroughly homogenized is lamellar throughout. These observations are obviously related to the recent work of PAYSON, HODAPP and LEEDER, presented to the ⊕ in 1939, on the spheroidizing of steel by isothermal transformation.

It now seems clear that the interesting results obtained by PAYSON apply only to heterogeneous austenite, containing free carbide and undissipated carbon concentration gradients, and it is clear also that the direct reaction product of homogeneous austenite is inevitably lamellar pearlite.

Let us now consider the formation of pearlite from austenite in simple carbon steels of eutectoid composition.

It is a common opinion that when pearlite forms from austenite, it first appears at the austenite grain boundaries, outlining them, with the envelope thickening with time until the austenite grains are entirely consumed, Fig. 3. Such a mode of transformation may be designated as "grain-boundary transformation". Since the pearlite in such samples forms at temperatures near that of the knee of the S-curve, it is not characteristic of transforma-

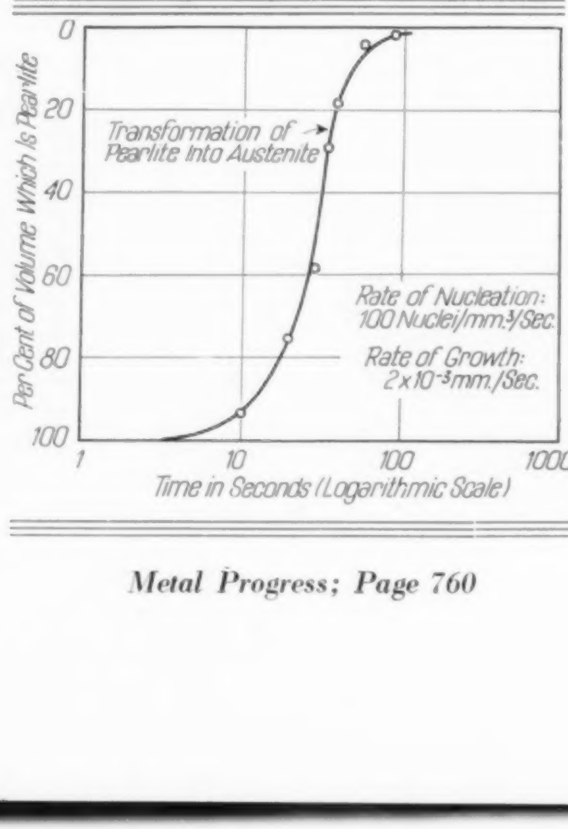


Fig. 2 — Typical Isothermal Reaction Curve. Points represent amount of homogeneous pearlite found by experiment to transform into austenite when held at 1375° F. Curve is calculated from the rates of nucleation and growth noted

tion of austenite at the higher temperatures.

At temperatures near Ae_1, pearlite again nucleates preferentially at the austenite grain boundary, but the nodules grow very large, transgressing grain boundaries and thus growing into and across grains not yet nucleated, absorbing many austenite grains before impinging upon another growing nodule. This mode of formation appears to be a general occurrence, yet for some reason it has hitherto escaped observation. This large pearlite nodule has been named the "group nodule", and the mode of transformation may be designated by "group-nodule transformation". The essential factor in its formation appears to be a rate of nucleation very low relative to the rate of growth.

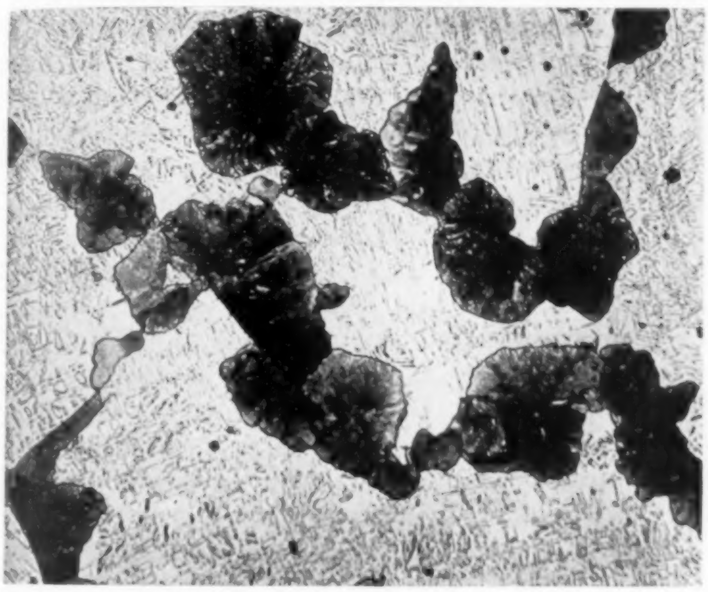


Fig. 3 — Grain-Boundary Transformation of Austenite into Pearlite Nodules. In this photograph at 1000 dia. by J. R. Vilella the dark nodules have little definable structure. The lighter matrix is fully hardened martensite (austenite transformed at low temperatures)

As we all know well, near the knee of the S-curve, pearlite nucleates again at the austenite grain boundary, and in a very short time the grain is outlined and enveloped in fine pearlite. Subsequent transformation consists largely in growth toward the center (but trans-boundary growth seems to occur, though to a far less marked degree). In any event, the rate of nucleation is large relative to the rate of growth, and the average pearlite nodule is much smaller than the austenite grain.

It is clear from the appearance of samples reacted near the knee of the S-curve (such as Fig. 3) that the rate of nucleation *within* the grain is extremely low, and this appears always to be true of *homogeneous* austenite. It is, then, the low rate of nucleation within the grain, together with a rate of nucleation at the grain boundary high compared to the rate of growth, that causes the austenite grain boundary to be clearly outlined and enables us to determine the austenite grain size by a gradient quench. But austenite is sometimes not homogeneous, and *heterogeneous* austenite (austenite containing free carbide) frequently provides a high rate of nucleation within the grain, and in this case it is difficult so to determine the austenite grain size.

The three variables determining the isothermal reaction curve for austenite → pearlite are the rate of nucleation per unit area of the grain boundary surface, the grain size (that is, the extent of the grain boundary surface) and the rate of pearlite grain growth. If two of these are held constant and only the grain size varied, its effect upon the isothermal reaction curve can be calculated. GROSSMANN applied the analysis in this way to the reaction precisely at the knee of the S-curve and was able to predict the effect of grain size alone upon the depth of hardening, and the effect of grain size upon steels of different hardenabilities. The predicted results are in very close agreement with depths of hardening actually observed.

The Nodular Troostite Question

We should now, I think, devote some attention to the nature of pearlite formed at the knee of the S-curve, for it is the rate of formation of pearlite at this point that determines hardenability.

It has, of course, been known for some time that the interlamellar spacing in pearlite decreases steadily as the temperature of formation decreases. As the reaction temperature is lowered, a product is obtained where the microscope can resolve only part of the nodule, and when the temperature is at the knee of the S-curve a product is obtained which frequently cannot be resolved in any part. Metallurgists have ordinarily been content to think that those portions which are not resolved by the microscope are nevertheless lamellar pearlite, but of

an interlamellar spacing too small for the resolution of the metallurgical microscope, as indeed was held by KOURBATOFF and BENEDICKS in 1905 and many metallurgists since. Yet there have been vigorous dissenters.

If we are to provide direct evidence on this question, we clearly need some method of observation providing a markedly greater degree of resolution than that characteristic of the best of metallurgical microscopes, and such a method is now available. During the last few years, the electron microscope, operating on electron-optical principles, has been developed, which is capable of yielding a degree of resolution for transparent substances up to 100,000 diameters magnification, roughly comparable to the resolution of the light-optical microscope at 1500 to 2500 diameters. This microscope will resolve distances as small as 100 to 150 Ångström units, and has made it possible to "see" large protein molecules. I shall show the first results of the application of the electron microscope to the study of steel, made in conjunction with our studies of pearlite. This work has been done in cooperation with V. K. ZWORYKIN of the Radio Corp. of America and his associates.

The electron microscope operates on the principle that a beam of electrons may be spherically diverted, on passing through a magnetic coil, in a manner analogous to the refraction which light waves suffer on passing through a lens, producing an analogous magnification. With a suitable system of such magnetic lenses, an electron beam may be passed through a sample more or less transparent to it, and a greatly magnified image obtained which may be viewed on a fluorescent screen or photographed.

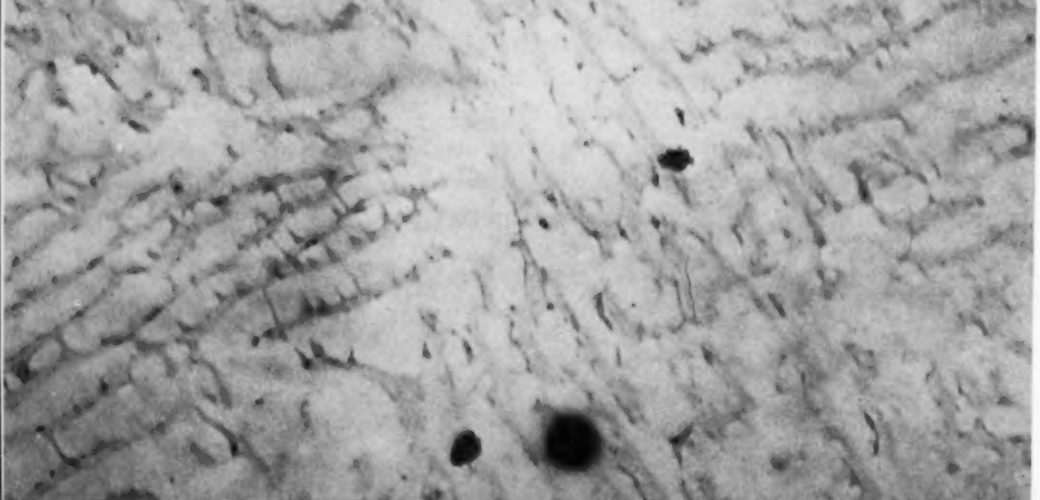
Metal samples, however, cannot be used directly on the present form of the electron microscope, for in usable sections metals are opaque to the electron beam, as they are to light. Reflection methods as employed in the metallurgical microscope are not available, and a different solution to the problem is necessary. This is found in the replica method adopted.

The technique in its present form consists in preparing a sample by the usual metallographic means and etching it for viewing at high magnifications. This sample is then coated with a layer of silver 0.1 mm. thick, deposited upon it by evaporation from massive silver; this layer is then stripped, its under surface bearing a minutely accurate contour replica of the surface of the sample. Upon this silver replica is placed an extremely thin layer of collodion, smooth on top, and the silver removed from it by solution in acid, yielding then a second replica, now a positive of the original steel surface. This thin second replica is then placed in the electron microscope and photographed. [Applause!]

Now this "collodion transmission electron-photomicrograph" is one in which the high spots on the original sample appear dark, for the collodion replica is thick there, and the low spots light, for there the replica is thin. The result is a contour photograph, differing in appearance somewhat from the ordinary photograph, losing some of its advantages, gaining others, and of course gaining greatly in magnification and resolution. With pearlite, cementite appears dark and ferrite light, as they do in ordinary photomicrographs.

Figure 4 is an electron microscope photomicrograph at a magnification of 25,000 diameters of a sample of pearlite formed isothermally at 1180° F.; it is a pearlite readily resolved by the ordinary microscope which is introduced here merely to show the general appearance of electron microscope pictures. It also shows what appears to be a characteristic of pearlite which becomes more pronounced as the temperature of formation is decreased, namely, that the

Fig. 4 — Electron Photomicrograph of Collodion Replica of Fine Pearlite Formed at 1180° F., Exhibiting Numerous Places Where Cementite Bridges the Intervening Ferrite Lamella. Magnification 25,000 diameters



cementite occasionally connects one cementite layer with the adjacent one. This bridging effect appears to be the more marked the finer the pearlite, as shown in a pearlite formed at 1075°F.

Figure 5 shows a pearlite formed at 1100° F., much nearer the knee of the S-curve, at a magnification of 30,000. It demonstrates the resolution that can be attained. This sample and many others — some 200 electron microscope photomicrographs have now been made — show no areas that cannot be resolved into lamellar pearlite, and it appears a reasonably safe conclusion that nodular troostite is in fact pearlite of a very small interlamellar spacing.

We are, then, evidently resolving structures which the ordinary microscope cannot resolve. I have selected the best photomicrographs of nodular troostite taken through the years with the ordinary microscope, and measured the minimum spacing which could be resolved; this spacing is 860 Ångström units. Similar studies on the photomicrographs taken in the electron microscope provide a minimum spacing of 300 Å, and it thus appears that a new degree of resolution has already been attained.

Samples of "upper bainite" provide very interesting electron microscope photomicrographs, as shown in Fig. 6, taken at 18,500 diameters. Here the light ferritic areas are clearly defined; note there is no clear registration of carbide particles.

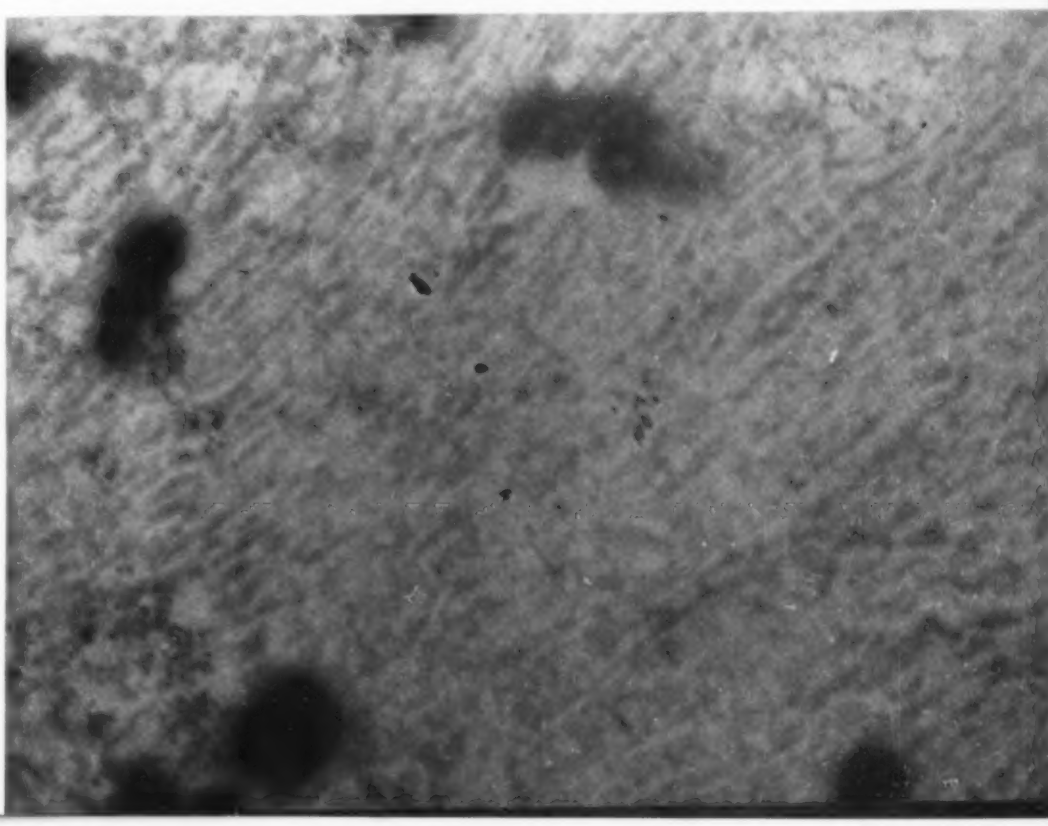
As a last demonstration of the possibilities of this technique, we may view a martensite tempered at 930° F. possessing a structure which under the ordinary microscope was poorly delineated, to say the least. The electron microscope photomicrograph (Fig. 7), at a magnification of 50,000 diameters, shows light-shaded islands of ferrite and what appears to be a fine carbide dispersion, with particles 0.8 mm. apart on the photograph clearly resolved, equivalent to an absolute distance of 150 Å or approximately 50 atom diameters. [Applause!]

[With these preliminary statements of principles and methods, the lecturer then presented evidence about specific factors which influence the rate of formation of pearlite. His first conclusion is that the rate of growth of a pearlite grain, once growth is started, is far less influenced by variations in microstructure and minor changes in composition than it is by the rate of nucleation. Pearlitic grain growth, then, is a "structure insensitive" property. The reasons for differences in hardenability in simple carbon eutectoid steels, depending on differences in the rate of formation of pearlite near the knee, must therefore be sought in differences in the rate of nucleation and not in the rate of growth. Of course, temperature is important; both the rate of grain growth and nucleation increase rapidly as the temperature lowers. Alloys also exercise distinct effects, but this lecture considers only eutectoid carbon steel.

[One surprising result of HULL's recent work at Carnegie Institute of Technology is that the nucleation rate is not a precise constant, as assumed in the earlier paragraphs, but increases with time. This behavior appears to be general, but since the total time at the knee of the S-curve is very short, only the average can be determined by present techniques and computations.]

The facts just recited refer to homogeneous austenite. But it seems clear to me that austenite as produced commercially is infrequently truly homogeneous. The various degrees of departure from this ideal state produce marked variations in rates of formation of pearlite, and in extreme degree produce variations in hardenability. It will be shown that these variations originate in differences in the rate of nucleation; it has already been shown that they cannot originate in differences in the rate of subsequent growth.

Fig. 5 — Electron Photomicrograph at 30,000 Diameters of Fine Pearlite (Irresolvable Optically) Which Was Formed Near the Knee of the S-Curve at 1100° F. Thinnest lamellae so far observed are about 300 Ångström units thick (100 atom diameters). Dark areas are silver particles undissolved from the collodion replica



It has been said that undissolved carbide and undissipated carbon concentration gradients are effective in determining hardenability, that is, the depth of hardening. BAIN stated this clearly in the seventh Campbell Lecture, citing a case where a steel with residual carbide hardened almost not at all, whereas the same steel, with all carbide dissolved, hardened throughout. MORRIS and MCQUAID at the ⚙ Hardenability Symposium in 1939 emphasized the necessity for thorough austenitizing to provide homogeneous austenite if full hardenability is to be realized, as did GORDON WILLIAMS last year, to select but a few of the references.

[In order to determine the effects of specific factors on the rate of nucleation, several series of experiments were cited. Samples of a single steel were austenitized for 30 min. at temperatures ranging from 1550 to 1950° F., and the relative rates of nucleation per sq.mm. of grain boundary area decreased steadily as the temperature rose. In this fairly uniform austenite prepared at a high temperature the pearlite nucleated at 1245° F. 120 times as fast in the sample austenitized at 1550° F. The effect of *time* at a single temperature was also studied. The steel was a commercial simple carbon eutectoid steel with 0.80% carbon, 0.74% manganese, silicon-killed; after austenitizing, it was reacted to pearlite at 1255° F. The austenitizing temperature was 1610° F. (near Ae_1), and the times of austenitizing varied from 5 to 90 min. Rates of nucleation varied by a factor of 1000; the fast rate being noted in the sample heated the shortest time above Ae_1, and containing observable undissolved particles of carbide.]

Similar studies for a reaction temperature of 1100° F., which is near the knee, give an important result: Differences in austenitizing time at 1610° F. still exert a sensible influence upon the rate of reaction and upon the rate of nucleation, but it is a very much smaller influence than that at nucleation temperatures near Ae_1 — a factor of 2 instead of a factor of 1000.

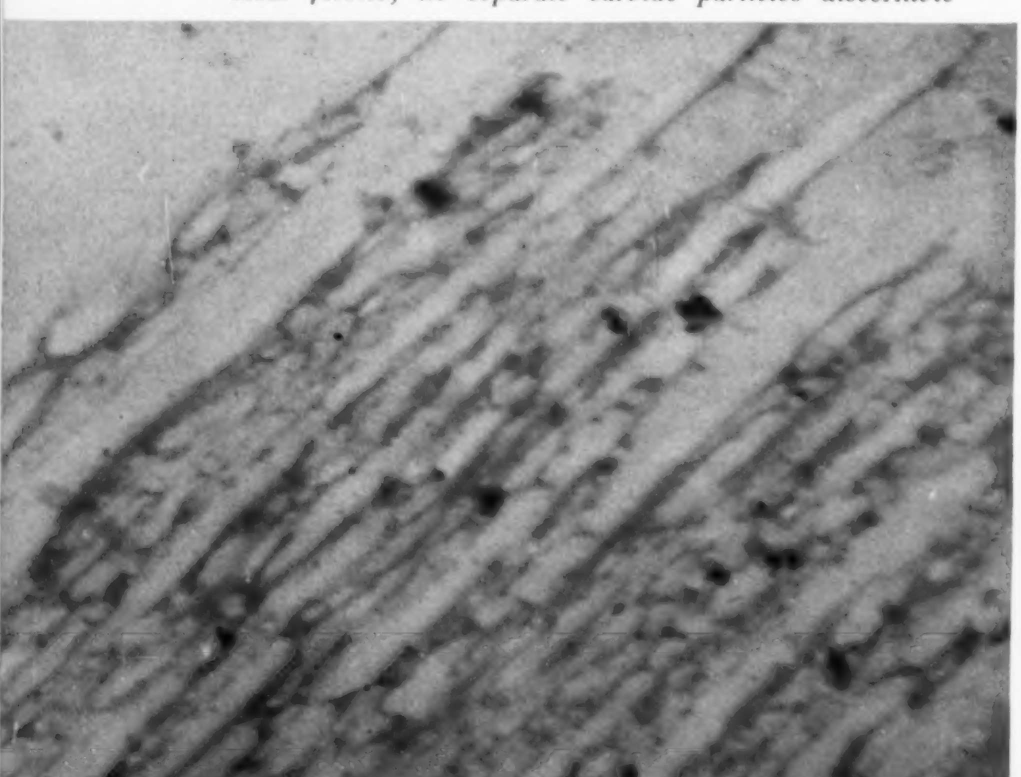
Evidently, then, the rate of reaction to coarse pearlite near Ae_1 is *far* more sensitive to small variations in homogeneity in austenite than the rate to fine pearlite near the knee. This fact should be of some importance in the heat treatment of very large sections which quench to pearlite, transforming at relatively high temperatures. It would appear that such sections should be homogenized unusually thoroughly in order to decrease the rate of formation of pearlite, and accordingly upon cooling to react at a lower temperature, giving a finer pearlite and thus a greater ductility and strength. Ordinary hardenability tests would be unreliable in predicting this behavior.

At the moment it appears that free carbide particles must be reasonably numerous and small to exert an appreciable effect upon hardenability, and it appears also that when such a condition obtains in austenite, pearlite tends to nucleate generally throughout the austenite grain and not solely at the grain boundary. Conversely, if in a hardenability test specimen the partially hardened zone exhibits pearlite nodules distributed generally and not restricted to nor even preferentially located at the austenite grain boundaries, it may be suspected that the steel in this condition is rapidly reacting, and therefore of low hardenability.

It is interesting that pure steels transform on treating from pearlite to austenite much more readily than commercial steels, and upon reverse transformation at the knee show practically nothing but grain-boundary nodules, whereas commercial steels, austenitizing much more slowly, frequently show general nucleation. COLTON has shown clearly that the more thorough the austenitizing treatment in commercial steels the more completely does the transformation occur at the grain boundary.

Steels with anomalous hardenabilities are frequently reported, but in at least many of these cases the reason does not lie in any mys-

Fig. 6 — Structure at 18,500 Diameters of Bainite Formed From Martensite Somewhat Below the Knee of the S-Curve. Clear ferrite; no separate carbide particles discernible



teri[…]s effect of furnace practice but in the uns[…]pected presence of carbide. In attempting div[…]ation of such cases, it would appear advisabl[…]o look first to the state of homogeneity of aus[…]nite; such differences produce differences in h[…]rdenability in the manner described.

E[…]FECT OF DEOXIDATION PRACTICE

The opinion is held by some that deoxidation practice has an influence upon the rate of formation of pearlite and upon hardenability apart from the effect of deoxidation upon grain size and apart from any effect of residual carbide. A number of such cases were cited at the Hardenability Symposium in 1939, and several others have been cited since in papers before this society. This opinion appears to rest on two bases — first, that since observers report differences in hardenability which they have been unable to attribute to differences in grain size or of composition, some effect must be present, possibly an unknown effect of deoxidation practice; second, that since inclusions are sometimes observed to exert a nucleating effect upon pearlite, variations in deoxidation practice, producing various types of inclusions, ought to produce differences in hardenability.

It is at least clear that a rigid distinction must be drawn between, on the one hand, the effect of deoxidation upon grain size and the effect which grain size has upon hardenability, and on the other hand, the effect which deoxidation products have upon hardenability entirely apart from any influence which grain size may have.

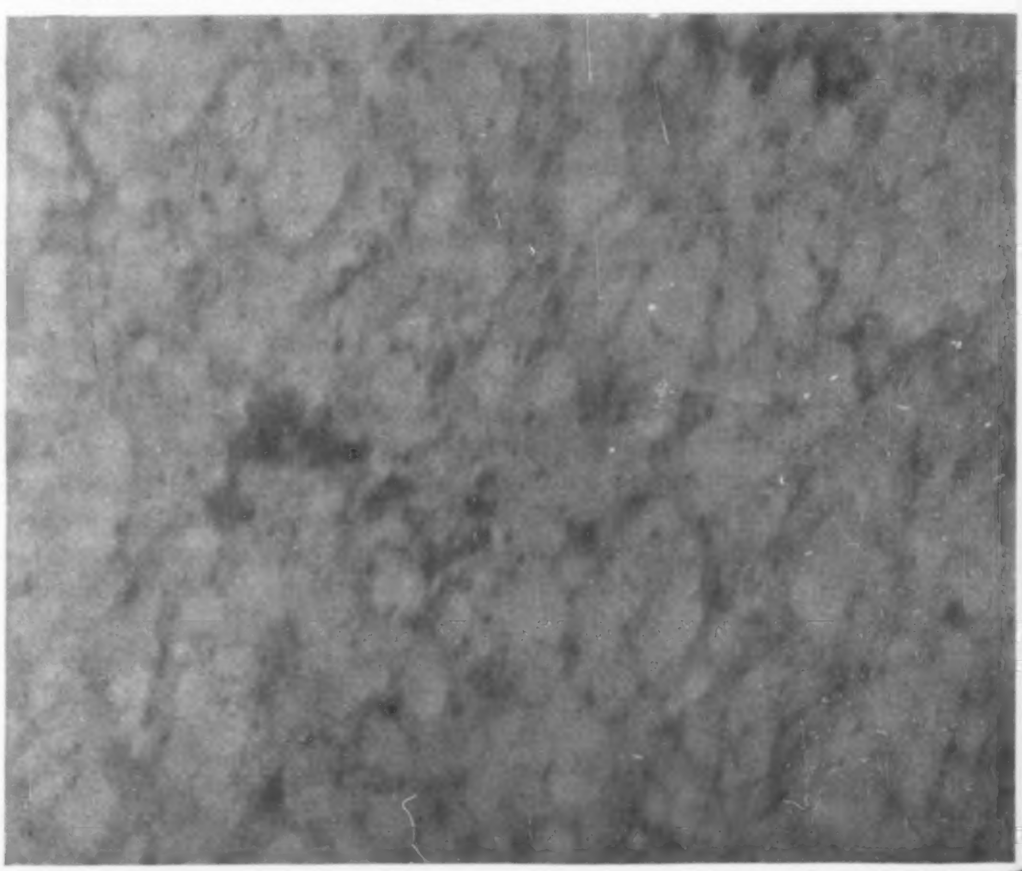
CASH, MERRILL, and STEPHENSON observed in 1939 that when a fine-grained part of a heat, deoxidized with aluminum, was annealed to give the same grain size as that of a coarse-grained part of the same heat, the depth of hardening was the same, and they drew the conclusion that deoxidation with aluminum affected hardenability only through its effect on grain size.

HULL has determined the rate of nucleation of these two steels at 1100° F. after austenitizing to a single grain size at temperatures high enough almost certainly to avoid any effect of carbon heterogeneity. There is a difference in the rates of nucleation, but only by a factor of four. COLTON has obtained similar data for rates of nucleation near the knee, at 1100° F., and these show a difference, but only by the small factor of two, inadequate to produce a measurable difference in hardenability. With the austenitizing treatments employed, no residual carbide could be detected, and nucleation was predominantly at the grain boundary. It is clear from this that such deoxidation exercises only a minor influence upon the rate of formation of pearlite at all temperatures.

There can be no doubt that deoxidation products can cause nucleation within the grain similar to that caused by residual carbide, as shown by BAIN in 1932 and as cited by MORRIS and MCQUAID and by GREENE in 1939, by GROSSMANN and STEPHENSON in 1941, and others, but the effect is slight. As BURNS showed in 1939, variations in residual alloy in commercial steel are ordinarily great enough in their effect upon hardenability much to exceed this.

Thus far, in summary, it appears to me a fair statement that variations in hardenability are brought about first by variations in grain size, as this is determined by deoxidation practice, affecting the rate of nucleation; second, by variations in composition — deliberate or accidental — affecting both the rate of nucleation and the rate of growth; and third, by inadequate carbide solution, affecting the rate of nucleation. There is no case proven as an exception to this of which I am aware, nor does it seem possible that there should be one in ordinary commercial steels.

Fig. 7 — Martensite, Tempered at 930° F., Magnified 50,000 Diameters. Fine carbides distinguished 50 atom diameters apart



CRITICAL POINTS

By the Editor

TWO REGRETTABLE ERRORS of omission occurred during the multitude of operations connected with the production of the big October issue. Certainly we should have given the grateful credit to Glenn L. Martin Co. for the loan of MELVIN JONES' fine painting used as art work on the covers. .....Also the story of shell production and heat treatment at Frankford Arsenal (page 509) was written by the officer in charge of the Artillery Ammunition Department, Lieut. Col. E. C. BOMAR. No one noted the absence of his "by-line" on page 509 until long after it was printed, when writing copy for the Table of Contents. .... Something's wrong with the inspection department.

Wailing wall

PASSED ROBERT WHEELER of International Nickel Co. while lost in the corridors of OPM's warren in Washington, where so many ASMembers are working on details of the defense program. BOB is interested primarily in saving more of the nickel in alloy steel scrap. Certain large steel producers have arrangements with large customers so they segregate armor plate and other alloy steel scrap to send it directly back for remelting. Perhaps 1,000,000 lb. of nickel a month is now recovered and re-used, but WHEELER is sure another million could be if the fabricators and steel plants would work together. It disturbed him to find that several carloads of S.A.E. 4820 turnings had gone into a plant making carbon steel, and he was particularly distressed by the current tendency to consider steels containing under 2% nickel not worth saving for their alloy content. To segregate is economic as well as patriotic. The present price schedule permits an $8 premium for scrap analyzing 2% nickel, and this should more than pay for the extra labor and accounting in the fabricating shops; it also contains $12 worth of recoverable nickel so the steel maker stands to save $4. If anyone wants to know how to segregate scrap, go to the Wright aero engine plant in Paterson, N. J., where FRANK KENT has installed a real system — at some expense, but it works.

Segregate that alloy steel scrap

OUT to the fine new Chrysler Engineering Building, as guest of the "Steel Standardization Group" at one of its monthly meetings. The group was organized over ten years ago by F. E. MCCLEARY, Chrysler's metallurgical engineer, and has since operated under MAC's energetic chairmanship. It has stuck close to its knitting, so to speak, its avowed purpose being to develop fool-proof testing methods, so any laboratory in any steel plant or in any of the Chrysler shops could check the results from any other. It had been amply proved that many important details of such universal tests as tensile, hardness and grain size were left to individual preference, and their accumulated effect introduced such variations in the results that producer and purchaser were frequently not speaking the same language — a situation often generating a great deal of heat but no light. Staff metallurgists of the principal steel suppliers (Bethlehem, Carnegie-Illinois, Great Lakes, Pittsburgh Crucible, Republic and Timken) have been members of this committee; seemingly the results of their arguments have been most salutary in many unexpected respects. The lion lies down with the lamb! .... The main committee has, among other things, been steering a so-called "B group" of men in the respective laboratories who have actually done the work and found out just what is the difference, say, between hardenability test pieces 3 in. long and 4 in. long. .... Knowledge of correct testing procedure has been only the start of far-reaching movements of economic importance. Shortly after the committee began its activities the Chrysler metallurgists were finding out how to apply the new fine-grained carbon-molybdenum steels. Quite naturally some of the original acceptance requirements were later found to be

A model of consumer-producer cooperation

unnecessary; during these years the steel companies also learned what special melting and rolling practices were really necessary. In the present national emergency, when molybdenum is our most plentiful alloying element, who can appraise the value of this accumulated knowledge? .... Since automotive steels are used *after* hardening, it early became apparent that the general — but very obscure — problem of hardenability should be studied, in addition to steel's static properties and its machinability. Consequently various hardenability tests have been under scrutiny for over five years. The records of this investigation alone fill several volumes, and finally it became apparent that the Jominy end-quench test was most suitable, and the exact details have been worked out. To mention only one economic result of the work: Steel producers now make hardenability tests on sample ingots cast from the electric or openhearth heat, and thus know what the nature of the metal is before the ingots come out of the soaking pits. The clear trend seems to be toward a relaxation of chemical limits; the steel of the future will probably be specified as a certain type; exact chemistry will be of minor importance to the purchaser as long as the steel falls within definite limits of hardenability.

TO THE ANNUAL MEETING of the Army Ordnance Association, held this year in Detroit rather than at Aberdeen Proving Ground. Industrialists, army officers, and civilian engineers lunched and dined sumptuously, and heard repeatedly that this was no time for relaxation of effort; great though the accomplishments have been, even greater must be attempted, and that immediately. Lacking specific figures, however, it has a vague and misty appearance to men accustomed to reaching definite goals, even though that high goal may mean 4,500,000 motor cars in a single year. .... The common denominator of all the technical addresses by men who are actually producing guns, tanks and powder is that *time* is needed to start to produce. For instance, the Bofors anti-aircraft gun mount was contracted to Firestone in Akron; it took four months to translate the Swedish metric drawings into American equivalents, plan their mass production by mass production methods, and produce two pilot units by toolroom methods. Chrysler took three months for the similar stint on the gun itself; a factory (to make ten per day) requires 900 machine tools, only 400 of which could be taken from the automotive shops. .... Highlight of the day was a visit to the tank arsenal, designed for a permanent factory and repair base. Building and equipment cost $20,000,000, and seven months was required to produce the first ready-for-combat unit — an amazing record for Chrysler's organization, but nevertheless requiring seven months of *time*. Thirteen months after ground was broken, the early production of one tank a day has been quadrupled; doubling the entire installation is in prospect. It's heartening to see a dozen of these 28-ton babies scurrying around the test track, in and out, up and down — and a line of flat cars, each with a pair of tanks blocked up, ready for shipment to the United States Army.

Time, the essence of arms production

PONDERED THIS POSER: If you employed six researchers for four years to develop a 1,000,000-volt X-ray apparatus that might sell six a year for perhaps eight or ten years, what should be the "development expense" item in the selling price? At a recent meeting in Schenectady, Director of Research COOLIDGE of General Electric did not answer that question, but he did point out that previous art had already developed 100,000, 200,000 and 400,000-volt portable X-ray machines, used by such pioneers as Watertown Arsenal, Aluminum Co. of America, and the industry making welded boilers. Also in existence is a massive 800,000-volt medical equipment, so the primary task was to build a 1,000,000-volt *portable* unit. It utilizes the fundamental principle of the preceding 800,000-volt machine (and the cyclotron "atom smasher"), namely that electrons shot off at relatively low speed (voltage) from a hot metal cathode are given a succession of swift kicks as they pass through appropriate electrical fields, each kick adding to their energy. Two fundamental improvements were required, however — one, the very compact "resonant transformer" without an iron core to create the electrical fields, and second, the use of freon gas for insulation (di-chlor-di-fluor-methane to you) with three times the dielectric strength of oil but 1/120 its weight. The electron tube is placed right along the axis of the transformer coils, where the iron core would be expected to be, and the tungsten target blocks off the square end of a water-cooled extension, some 2 ft. out in the clear.

X-ray tube as powerful as radium

Here the sharply focused electron stream is converted into X-rays and they emerge in all directions — in this respect the source resembles a radium capsule. So the tube can be poked through the end of a drum and an entire circumferential seam radiographed at once; or a number of objects set in appropriate fixtures about this energy center for simultaneous inspection. At Henry Ford's laboratory, for instance, six cast crankshafts are arranged around the rim of a wheel and radiographed simultaneously. A. J. Moses of Combustion Engineering Co. says the new equipment is absolutely necessary to inspect drums made of 5½-in. plate (welded rather than seamless because suitable forging equipment is working on other items). . . . . It's all very mysterious. Here is a stream of electrons — supposedly particles of electricity — moved along at 1,000,000-volt potential and close to the speed of light, but with the relatively low penetrating power of ¼ in. of human flesh. These electrons hit the tungsten and are stopped cold, but the energy is converted into a wave form (whatever that means), X-rays which penetrate a foot of steel. Maybe it's the conservation of "size times penetrating power"; electrons with million-volt velocities have some size but little penetrating power; X-rays have no mass and enormous penetrating power. . . . . David Basch, General Electric's consultant on metallic materials and processes, says that the fluoroscope is now much used for 100% inspection of white metal castings. The sensitivity is about 7% and, since the maximum wall thickness is about ¼ in., defects on the order of 15 thousandths can be seen. . . . . Beware, however, of the industrial disease racket. Amoebic conditions may be due to a hundred causes other than X-ray exposure but if X-ray outfits move around the shop it will be easy meat for ambulance chasers.

Thoughts on metal shortages

WONDERING much over the shortages in metal supplies in this the richest of all metallurgical nations, yet convinced that some of the deficits are anticipated rather than actual. Comparing official statements made at intervals, one always finds far greater increases in consumption than increases in production. This is explainable by the fact that mines, smelters and refineries always have been operated continuously — 24 hr. daily. There aren't any more hours. On the other hand, most consuming plants have been on a 40-hr. week, and (potentially) their appetite for raw material can be expanded four-fold merely by working 'round the clock. . . . . Some errors are inherent in such estimates of supply and demand. Generally the conclusion is less favorable than warranted by the true situation, because production and inventories tend to be under-estimated and consumption over-estimated. Production gradually exceeds 100% of rated capacity as bottlenecks are eliminated, improved practices adopted (such as charging hot rather than cold metal to electric refining furnaces) and attention concentrated on fewer products and those the ones most adaptable. Requirements are always over-estimated in order to be on the safe side — the king who lost his kingdom for want of a horseshoe nail would gladly have had a whole kegful in the farrier's van. Hence the military idea that you ask for twice what you think you'll need, and then you have half enough! . . . . . This results in some illogical situations. In the 1942 figures enough tungsten, molybdenum and vanadium are "reserved" for toolsteel production at nearly double the current rate, yet the current rate is at practical capacity of the American industry. Another instance: "Orphan" aluminum from remelted scrap and first runs in new aluminum reduction pots is accumulating at the rate of millions of pounds monthly; the armed services don't want it for castings for it is off-analysis, and civilian industry can't get it because of tight priorities. It might do for the thermit filling of incendiary bombs, if we had any magnesium to make the bomb cases. (Of course almost any aluminum that would cast would serve as a case.) . . . On the other hand, early and vigorous attention to some of the strategic metals has proven a God-send. Tin is entirely imported over long distances, and is being consumed at a record rate. Yet the government stockpile grows steadily, if slowly, month by month, and a report from a large alloy maker only recently said that "it has been available in a perfectly normal way". Likewise we will have our own smelter making tin from Bolivian ores early in 1942. Again: Manganese — a metal plentiful at home but existing in un-wanted ores — is normally held in privately owned stockpiles to about a year's supply. This has been increased materially; Anaconda is producing 60% nodules at the rate of 125,000 tons a year; Cuban output is increasing; other American sources are in preparation; and the ordnance department is willing to save one-third the alloy in its shell steel.

A. I. S. I. Standard Steel Compositions

Basic* Openhearth Alloy and Electric Furnace Carbon and Alloy Steels

(Blooms, Billets, Slabs, Bars and Hot Rolled Strip)

Code	C	Mn	P Max.*	S Max.*	Si*	Ni	Cr	Mo
A 1320	0.17-0.22	1.80-2.10	0.040	0.040	0.20-0.35	....	....	....
A 1321	0.18-0.23	1.60-1.90	0.040	0.040	0.15-0.30	....	....	....
A 1330	0.28-0.33	1.60-1.90	0.040	0.040	0.15-0.30	....	....	....
A 1335	0.33-0.38	1.60-1.90	0.040	0.040	0.15-0.30	....	....	....
A 1340	0.38-0.43	1.60-1.90	0.040	0.040	0.15-0.30	....	....	....
A 2317	0.15-0.20	0.40-0.60	0.040	0.040	0.15-0.30	3.25-3.75	....	....
A 2330	0.28-0.33	0.60-0.80	0.040	0.040	0.15-0.30	3.25-3.75	....	....
A 2335	0.33-0.38	0.60-0.80	0.040	0.040	0.15-0.30	3.25-3.75	....	....
A 2340	0.38-0.43	0.70-0.90	0.040	0.040	0.15-0.30	3.25-3.75	....	....
E 2512	0.09-0.14	0.45-0.60	0.025	0.025	0.15-0.30	4.75-5.25	....	....
A 2514	0.12-0.17	0.40-0.60	0.040	0.040	0.15-0.30	4.75-5.25	....	....
E 2517	0.15-0.20	0.45-0.60	0.025	0.025	0.15-0.30	4.75-5.25	....	....
A 3045	0.43-0.48	0.75-0.95	0.040	0.040	0.15-0.30	0.60-0.80	0.60-0.80	....
A 3115	0.13-0.18	0.40-0.60	0.040	0.040	0.15-0.30	1.10-1.40	0.55-0.75	....
A 3120	0.17-0.22	0.60-0.80	0.040	0.040	0.15-0.30	1.10-1.40	0.55-0.75	....
A 3130	0.28-0.33	0.60-0.80	0.040	0.040	0.15-0.30	1.10-1.40	0.55-0.75	....
A 3135	0.33-0.38	0.60-0.80	0.040	0.040	0.15-0.30	1.10-1.40	0.55-0.75	....
A 3140	0.38-0.43	0.70-0.90	0.040	0.040	0.15-0.30	1.10-1.40	0.55-0.75	....
A 3141	0.38-0.43	0.70-0.90	0.040	0.040	0.15-0.30	1.10-1.40	0.70-0.90	....
A 3145	0.43-0.48	0.70-0.90	0.040	0.040	0.15-0.30	1.10-1.40	0.70-0.90	....
A 3150	0.48-0.53	0.70-0.90	0.040	0.040	0.15-0.30	1.10-1.40	0.70-0.90	....
A 3240	0.38-0.45	0.40-0.60	0.040	0.040	0.15-0.30	1.65-2.00	0.90-1.20	....
E 3310	0.08-0.13	0.45-0.60	0.025	0.025	0.15-0.30	3.25-3.75	1.40-1.75	....
E 3316	0.14-0.19	0.45-0.60	0.025	0.025	0.15-0.30	3.25-3.75	1.40-1.75	....
A 4023	0.20-0.25	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4024	0.20-0.25	0.70-0.90	0.040	(a)	0.20-0.35	....	....	0.20-0.30
A 4027	0.25-0.30	0.70-0.90	0.040	(a)	0.20-0.35	....	....	0.20-0.30
A 4032	0.30-0.35	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4037	0.35-0.40	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4042	0.40-0.45	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4047	0.45-0.50	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4063	0.60-0.67	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4065	0.62-0.70	0.70-0.90	0.040	0.040	0.20-0.35	....	....	0.20-0.30
A 4119	0.17-0.22	0.70-0.90	0.040	0.040	0.15-0.30	....	0.45-0.65	0.20-0.30
A 4120	0.17-0.22	0.70-0.90	0.040	0.040	0.15-0.30	....	0.60-0.80	0.20-0.30
A 4130	0.28-0.33	0.40-0.60	0.040	0.040	0.15-0.30	....	0.80-1.10	0.15-0.25
E 4132	0.30-0.35	0.40-0.60	0.025	0.025	0.15-0.30	....	0.80-1.10	0.18-0.25
A 4134	0.32-0.37	0.40-0.60	0.040	0.040	0.15-0.30	....	0.80-1.10	0.15-0.25
E 4135	0.33-0.38	0.70-0.90	0.025	0.025	0.15-0.30	....	0.80-1.10	0.18-0.25
E 4137	0.35-0.40	0.70-0.90	0.025	0.025	0.15-0.30	....	0.80-1.10	0.18-0.25
A 4142	0.40-0.45	0.75-1.00	0.040	0.040	0.15-0.30	....	0.80-1.10	0.15-0.25
A 4143	0.40-0.45	0.75-1.00	0.040	0.040	0.15-0.30	....	0.80-1.10	0.30-0.40
E 4150	0.48-0.53	0.70-0.90	0.025	0.025	0.15-0.30	....	0.80-1.10	0.20-0.27
A 4317	0.15-0.20	0.45-0.65	0.040	0.040	0.15-0.30	1.65-2.00	0.40-0.60	0.20-0.30
A 4320	0.17-0.22	0.45-0.65	0.040	0.040	0.15-0.30	1.65-2.00	0.40-0.60	0.20-0.30
A 4337	0.35-0.40	0.60-0.80	0.040	0.040	0.15-0.30	1.65-2.00	0.60-0.80	0.30-0.40
E 4337	0.35-0.40	0.60-0.80	0.025	0.025	0.15-0.30	1.65-2.00	0.70-0.90	0.23-0.30
E 4340	0.40-0.45	0.60-0.80	0.025	0.025	0.15-0.30	1.65-2.00	0.70-0.90	0.23-0.30
A 4608	0.06-0.11	0.40 max.	0.040	0.040	0.20 max.	1.40-1.75	....	0.15-0.25
A 4615	0.13-0.18	0.45-0.65	0.040	0.040	0.15-0.30	1.65-2.00	....	0.20-0.30
E 4617	0.15-0.20	0.45-0.65	0.025	0.025	0.20-0.35	1.65-2.00	....	0.20-0.27
A 4620	0.17-0.22	0.45-0.65	0.040	0.040	0.15-0.30	1.65-2.00	....	0.20-0.30
E 4620	0.17-0.22	0.45-0.60	0.025	0.025	0.20-0.35	1.65-2.00	....	0.20-0.27
A 4621	0.18-0.23	0.70-0.90	0.040	0.040	0.15-0.30	1.65-2.00	....	0.20-0.30
E 4640	0.38-0.43	0.60-0.80	0.025	0.025	0.15-0.30	1.65-2.00	....	0.20-0.27
A 4815	0.13-0.18	0.40-0.60	0.040	0.040	0.15-0.30	3.25-3.75	....	0.20-0.30
A 4821	0.18-0.23	0.50-0.70	0.040	0.040	0.15-0.30	3.25-3.75	....	0.20-0.30
A 5045	0.43-0.48	0.70-0.90	0.040	0.040	0.15-0.30	....	0.55-0.75	....
A 5120	0.17-0.22	0.70-0.90	0.040	0.040	0.15-0.30	....	0.70-0.90	....
A 5130	0.28-0.33	0.70-0.90	0.040	0.040	0.15-0.30	....	0.80-1.10	....
A 5145	0.43-0.48	0.70-0.90	0.040	0.040	0.15-0.30	....	0.70-0.90	....
A 5150	0.45-0.55	0.70-0.90	0.040	0.040	0.15-0.30	....	0.90-1.20	....
A 5152	0.47-0.55	0.70-0.90	0.040	0.040	0.15-0.30	....	0.70-0.90	....
E52095	0.90-1.00	0.30-0.50†	0.025	0.025	0.20-0.35	....	0.45-0.65	....
E52098	0.90-1.05	0.30-0.50†	0.025	0.025	0.20-0.35	....	1.00-1.25	....
E52099	0.90-1.05	0.30-0.50†	0.025	0.025	0.20-0.35	....	1.30-1.65	....
E52100	0.95-1.10	0.30-0.50†	0.025	0.025	0.20-0.35	....	1.20-1.50	....
E52101	0.95-1.10	0.30-0.50†	0.025	0.025	0.20-0.35	....	1.30-1.65	....
E52107	1.00-1.15	0.30-0.50†	0.025	0.025	0.20-0.35	....	1.35-1.65	....
A 6120	0.17-0.22	0.70-0.90	0.040	0.040	0.15-0.30	....	0.70-0.90	0.10 min.V
E 6150	0.47-0.53	0.70-0.90	0.025	0.025	0.15-0.30	....	0.80-1.10	0.15 min.V
A 6152	0.48-0.55	0.70-0.90	0.040	0.040	0.15-0.30	....	0.80-1.10	0.10 min.V
A 9255	0.50-0.60	0.70-0.90	0.040	0.040	1.80-2.20	....	....	....
A 9260	0.55-0.65	0.70-0.90	0.040	0.040	1.80-2.20	....	....	....
A 9262	0.55-0.65	0.70-0.90	0.040	0.040	1.80-2.20	....	0.20-0.30	....
A 9263	0.55-0.65	0.70-0.90	0.040	0.040	1.80-2.20	....	0.30-0.40	....

*Lowest standard maximum phosphorus or sulphur content for acid openhearth or electric furnace alloy steel is 0.05% each; silicon is 0.15% min.

†These steels may be specified to either 0.30 to 0.45% or 0.35 to 0.50% manganese, but it is recommended that the full range be allowed wherever possible.

NOTE (a)—Sulphur range: 0.035 to 0.050%.

Basic Openhearth Phosphorized Carbon Steels

Code	Semi-finish	Bars	Rods	C	Mn	P Note (b)	S
C 1205	√	—	√	0.08 max.	0.25-0.40	0.04-0.07	0.05 max.
C 1206	—	—	√	0.08 max.	0.25-0.40	0.06-0.10	0.05 max.
C 1209	—	—	√	0.08-0.13	0.30-0.50	0.04-0.07	0.05 max.
C 1210	√	—	√	0.08-0.13	0.30-0.50	0.06-0.10	0.05 max.
C 1211	—	—	√	0.08-0.13	0.60-0.90	0.09-0.13	0.10-0.15

Acid Bessemer Sulphurized Carbon Steels

Code	Bars	Rods	C	Mn	P	S (b)
B 1106	—	√	0.09 max.	0.50 max.	0.11 max.	0.04-0.09
B 1110	√	√	0.13 max.	0.60 max.	0.11 max.	0.045-0.075
B 1111	√	√	0.08-0.13	0.60-0.90	0.09-0.13	0.10-0.15
B 1112	√	√	0.08-0.13	0.60-0.90	0.09-0.13	0.16-0.23
B 1113	√	√	0.08-0.13	0.60-0.90	0.09-0.13	0.23-0.32

(b)—Sulphurized (and phosphorized) steel is not subject to check analysis for sulphur (or phosphorus).

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Basic Openhearth and Acid Bessemer Carbon Steels

Code	Semi-finish	Bars	Rods	C	Mn	P Max.	S Max.
C 1005	—	—	√	0.06 max.	0.35 max.	0.04	0.05
C 1006	√	√	√	0.08 max.	0.25-0.40	0.04	0.05
C 1008	√	√	√	0.10 max.	0.30-0.50	0.04	0.05
CB 1008	—	√	√	0.10 max.	....	....	....
C 1010	√	√	√	0.08-0.13	0.30-0.50	0.04	0.05
C 1012	√	√	√	0.10-0.15	0.30-0.50	0.04	0.05
CB 1012	—	√	—	0.15 max.	....	....	....
C 1013	—	—	√	0.11-0.16	0.60-0.90	0.04	0.05
C 1014	√	√	√	0.13-0.18	0.30-0.50	0.04	0.05
C 1015	√	√	√	0.13-0.18	0.40-0.60	0.04	0.05
C 1016	√	√	√	0.13-0.18	0.60-0.90	0.04	0.05
CB 1017	√	√	—	0.10-0.25	....	....	....
C 1017	√	√	√	0.15-0.20	0.40-0.60	0.04	0.05
C 1018	√	√	√	0.15-0.20	0.60-0.80	0.04	0.05
C 1019	√	√	√	0.15-0.20	0.70-1.00	0.04	0.05
C 1020	√	√	√	0.18-0.23	0.30-0.50	0.04	0.05
C 1021	√	√	√	0.18-0.23	0.40-0.60	0.04	0.05
C 1022	√	√	√	0.18-0.23	0.70-1.00	0.04	0.05
C 1023	√	√	√	0.20-0.25	0.30-0.50	0.04	0.05
C 1025	√	√	√	0.22-0.28	0.30-0.50	0.04	0.05
C 1026	√	√	√	0.22-0.28	0.40-0.60	0.04	0.05
C 1027	—	—	√	0.24-0.30	0.40-0.60	0.04	0.05
C 1029	√	√	—	0.25-0.31	0.60-0.90	0.04	0.05
C 1030	√	√	√	0.28-0.34	0.60-0.90	0.04	0.05
CB 1032	—	√	—	0.25-0.40	....	....	....
C 1033	√	√	—	0.30-0.36	0.60-0.90	0.04	0.05
C 1034	—	—	√	0.32-0.38	0.50-0.70	0.04	0.05
C 1035	√	√	√	0.32-0.38	0.60-0.90	0.04	0.05
C 1038	√	√	√	0.35-0.42	0.60-0.90	0.04	0.05
C 1040	√	√	√	0.37-0.44	0.60-0.90	0.04	0.05
C 1041	—	—	√	0.36-0.44	1.35-1.65	0.04	0.05
C 1042	—	√	—	0.40-0.47	0.60-0.90	0.04	0.05
C 1043	√	√	—	0.40-0.47	0.70-1.00	0.04	0.05
C 1044	—	—	√	0.43-0.50	0.50-0.70	0.04	0.05
C 1045	√	√	—	0.43-0.50	0.60-0.90	0.04	0.05
C 1046	—	√	—	0.43-0.50	0.70-1.00	0.04	0.05
C 1050	√	√	—	0.45-0.55	0.60-0.90	0.04	0.05
C 1051	—	—	√	0.45-0.56	0.85-1.15	0.04	0.05
C 1054	—	—	√	0.50-0.60	0.50-0.70	0.04	0.05
C 1055	√	√	—	0.50-0.60	0.60-0.90	0.04	0.05
C 1057	—	—	√	0.50-0.61	0.85-1.15	0.04	0.05
C 1059	—	√	√	0.55-0.65	0.50-0.70	0.04	0.05
C 1060	—	—	√	0.55-0.65	0.60-0.80	0.04	0.05
C 1061	—	√	—	0.54-0.65	0.75-1.05	0.04	0.05
C 1062	—	—	√	0.54-0.65	0.85-1.15	0.04	0.05
C 1064	—	√	√	0.60-0.70	0.50-0.70	0.04	0.05
C 1066	—	—	√	0.60-0.71	0.80-1.10	0.04	0.05
C 1068	—	√	—	0.65-0.75	0.50 max.	0.04	0.05
C 1069	—	—	√	0.65-0.75	0.50-0.70	0.04	0.05
C 1073	—	√	√	0.68-0.78	0.50-0.70	0.04	0.05
C 1074	—	√	√	0.70-0.80	0.50-0.70	0.04	0.05
C 1075	—	—	√	0.70-0.80	0.60-0.80	0.04	0.05
C 1078	—	√	√	0.70-0.85	0.30-0.50	0.04	0.05
C 1080	—	√	—	0.70-0.85	0.60-0.90	0.04	0.05
C 1083	—	√	√	0.80-0.95	0.30-0.50	0.04	0.05
C 1085	√	√	—	0.80-0.95	0.60-0.90	0.04	0.05
C 1095	—	√	√	0.90-1.05	0.30-0.50	0.04	0.05
B 1006	—	—	√	0.08 max.	0.45 max.	0.11	0.06
B 1008	—	√	—	0.10 max.	0.30-0.50	0.11	0.06
B 1011	—	√	√	0.13 max.	0.50-0.70	0.11	0.06

NOTE: The listed standard openhearth steels only may be ordered with a silicon content of 0.07% maximum; 0.07 to 0.15%; 0.10 to 0.20%; or 0.15 to 0.30%.

Basic Openhearth Sulphurized Carbon Steels

Code	Semi-finish	Bars	Rods	C	Mn	P Max.	S (b)
C 1108	—	—	√	0.08-0.13	0.50-0.70	0.045	0.07-0.12
C 1109	√	√	√	0.08-0.13	0.60-0.90	0.045	0.08-0.13
C 1110	—	√	√	0.08-0.13	0.60-0.90	0.045	0.10-0.15
C 1111	—	—	√	0.08-0.13	0.60-0.90	0.045	0.16-0.23
C 1112	—	√	—	0.10-0.16	1.00-1.30	0.045	0.08-0.13
C 1113	√	√	—	0.10-0.16	1.00-1.30	0.045	0.23-0.32
C 1115	√	√	√	0.13-0.18	0.70-1.00	0.045	0.08-0.13
C 1116	√	√	√	0.13-0.18	0.70-1.00	0.045	0.10-0.15
C 1117	—	√	√	0.14-0.20	1.00-1.30	0.045	0.08-0.13
C 1118	√	√	√	0.14-0.20	1.30-1.60	0.045	0.08-0.13
C 1119	—	—	√	0.14-0.20	1.35-1.65	0.045	0.16-0.23
C 1120	√	√	√	0.18-0.23	0.60-0.90	0.045	0.08-0.13
C 1121	√	√	√	0.18-0.23	0.70-1.00	0.045	0.08-0.13
C 1122	√	√	√	0.17-0.23	1.35-1.65	0.045	0.08-0.13
C 1132	√	√	√	0.27-0.34	1.35-1.65	0.045	0.08-0.13
C 1137	√	√	√	0.32-0.39	1.35-1.65	0.045	0.08-0.13
C 1140	√	√	—	0.37-0.44	0.60-0.90	0.045	0.04-0.07
C 1145	√	√	—	0.42-0.49	0.70-1.00	0.045	0.04-0.07

NOTE: The standard steels C 1140 and C 1145 listed in this table may be ordered with a silicon content of 0.07% maximum; 0.07 to 0.15%; 0.10 to 0.20%; or 0.15 to 0.30%.

Acid Openhearth Carbon Steel Wire Rods

Code	C	Mn	P Max.	S Max.
D 1034	0.32-0.38	0.50-0.70	0.05	0.05
D 1049	0.43-0.50	0.50-0.70	0.05	0.05
D 1054	0.50-0.60	0.50-0.70	0.05	0.05
D 1059	0.55-0.65	0.50-0.70	0.05	0.05
D 1064	0.60-0.70	0.50-0.70	0.05	0.05
D 1069	0.65-0.75	0.40-0.60	0.05	0.05
D 1074	0.70-0.80	0.40-0.60	0.05	0.05
D 1078	0.70-0.85	0.30-0.50	0.05	0.05
D 1083	0.80-0.95	0.30-0.50	0.05	0.05
D 1095	0.90-1.05	0.30-0.50	0.05	0.05

NOTE: The standard steels listed in this table may be ordered with a silicon content of 0.10 to 0.25%; or 0.15 to 0.35%.

CODE: A is basic openhearth alloy steel.
B is acid bessemer carbon steel.
C is basic openhearth carbon steel.
D is acid openhearth carbon steel.
E is electric furnace steel.


ALLOYS
Timely information about metals...
CATALOGUED for your convenience
Specific answers to many of your questions about the selection, fabrication and uses of Nickel alloys are available to you quickly from our files.
This fund of helpful information we have gathered, checked and condensed into convenient printed form. The graphs, charts and shop guides are especially useful to men handling new materials or performing unfamiliar operations . . . and to new employees. This literature is available on request.
You are also offered the assistance of our technical staff in solving material problems arising from a temporary lack of Nickel. These engineers are offering timely suggestions to many vital industries during the present emergency.
Why not drop us a card asking for list of available literature. Your request for the assistance will receive prompt attention.
NICKEL

At a recent meeting in Schenectady, where the engineering applications of a 1,000,000-volt X-ray tube were demonstrated on heavy turbine castings, Mr. Moses (welding engineer turned manager) described the advantages in time, sensitivity and penetration of such high power radiography when examining seams in welded vessels. Welding of drums 5 in. or more thick in the walls is now necessary; such vessels were formerly forged and seamless, but now all the suitable heavy presses are preempted for other defense work.

TEN YEARS' PROGRESS IN RADIOGRAPHY

By A. J. MOSES
General Manager, Hedges-Walsh-Weidner Div., Combustion Engineering Co.

DEVELOPMENT and improvement of industrial X-ray apparatus has been a major factor in progress in manufacturing fusion welded, heavy-wall pressure vessels. The improvements made in the sensitivity of this non-destructive test have surpassed expectations; and the reduction made in the time required for making such tests have been rather startling. For instance, a few years ago we were forced to painstaking technique and cumbersome aids in order to make sure that radiographs would disclose cracks in 4-in. welds of the order of ½ in. in depth. Today we can detect cracks ⅛ in. deep in 6-in. welds. Up until two months ago it was requiring 7½ hr. to take an X-ray picture of 12 lineal inches of welds 5⅜ in. thick. Today, 24 lineal inches of these welds are being taken in 15 min. — a reduction in time of 60 to 1!

Before discussing the latest major improvement in industrial X-ray apparatus, a development of the first magnitude, I think you would be interested in a brief review of its application to heavy welded pressure vessels during the past ten years. Their welding is a hazardous venture and considered unsafe in the absence of a reliable non-destructive test. The X-ray was accepted as a reliable test for such welding in the boiler industry ten years ago. At that time, which was just prior to the acceptance of fusion welding in the manufacture of boiler drums by the American Society of Mechanical Engineers' Boiler Code Committee, my company, the Combustion Engineering Co., purchased from the General Electric X-Ray Corp. the apparatus shown in the first engraving. This was a 2-tube, 200,000-volt, air-cooled outfit. At that time we were very much pleased with the equipment, and while no one had had much experience in the X-raying of extremely heavy plate thicknesses, for the average thicknesses encountered at that time it was very satisfactory.

We were dealing with weld thicknesses from ½ to 2½ in., but the demand for greater thicknesses was increasing all the time. From the experience gained in making repairs in light and heavy welds, we soon came to the realization that this equipment had serious limitations as regards reliable sensitivity and reasonable exposure time. In the heavier plate ranges practically all of the X-ray pictures of welds over 2 in. were showing up as perfect welds, which was not at all reasonable.

At that time the General Electric X-Ray Corp. was preparing to bring out its 300,000-volt industrial unit. In fact, I believe several of these air-cooled units were manufactured; however, these were to be quickly superseded by a 300,000-volt oil-immersed apparatus. During

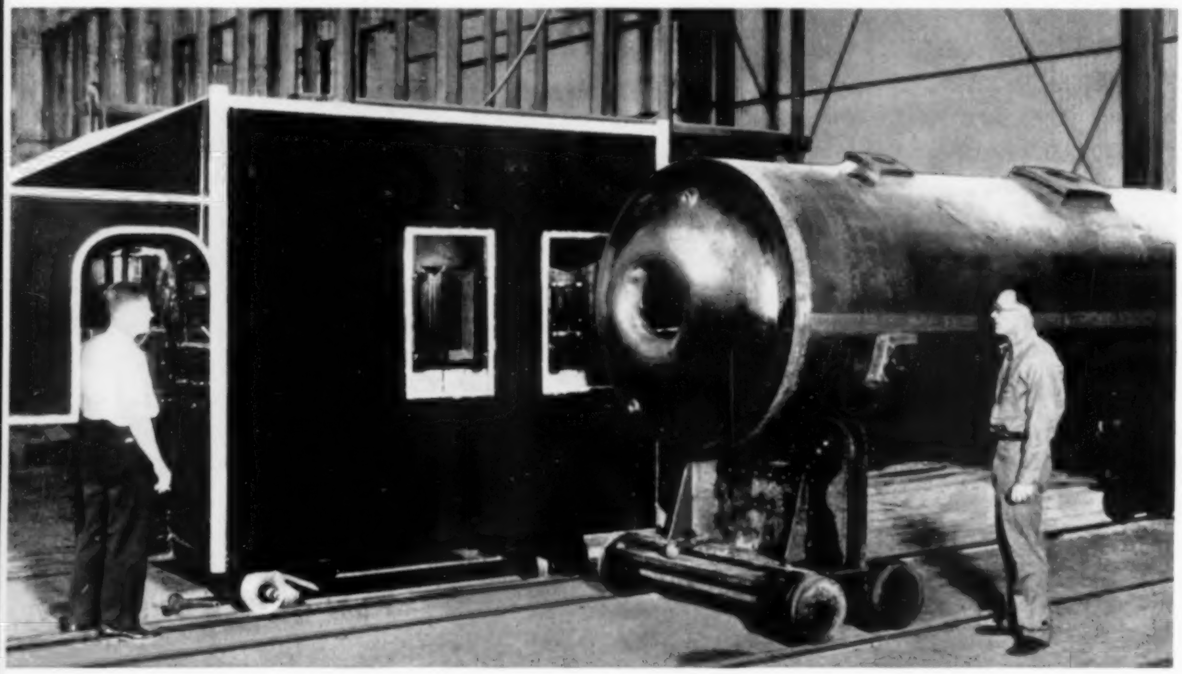


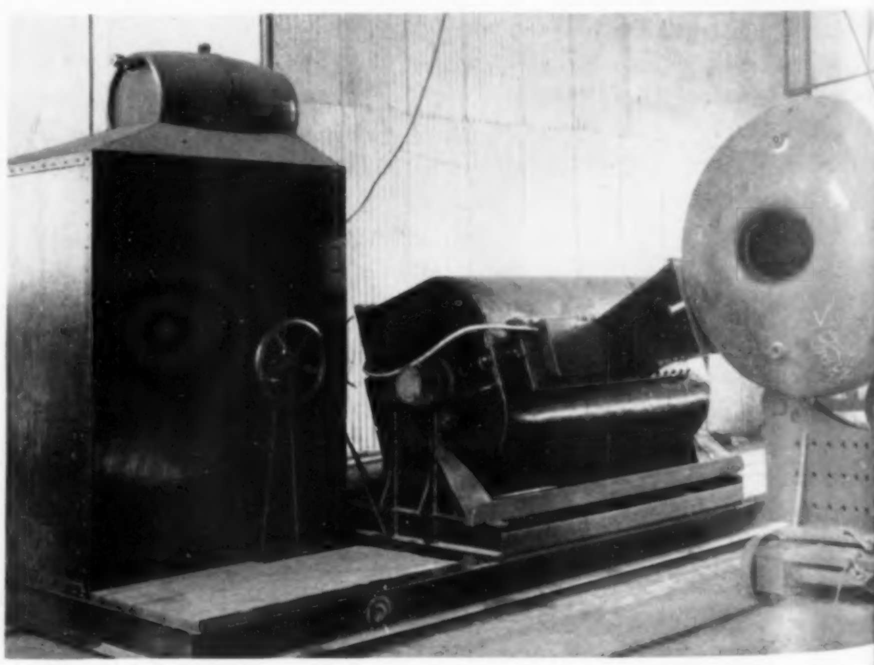
Fig. 1 — First X-Ray Equipment at Chattanooga Plant of Combustion Engineering Co., Inc. (Hedges-Walsh-Weidner Division) Was a 2-Tube 200,000-Volt, Air-Cooled Outfit in a Movable Shelter

this time, in the light of our experience, we were questioning whether higher voltages would help the situation much, unless better (more sensitive) radiographs could be obtained. Thereupon, we jointly undertook a thorough investigation of the matter, which required many months. In the meantime, on thicknesses over 2 in., we established the practice of double X-raying — once on partly finished joints with the weld metal at an interstage thickness, at which we could be sure of detecting important defects with the X-ray apparatus available, and the second time after the welding was completed, with the hope of detecting any gross defects that might arise or occur subsequent to the first X-raying. This procedure was most laborious, time consuming and expensive.

The 300,000-volt machine, which was the second machine purchased by us, is shown in Fig. 2. This was an oil-immersed outfit, and takes much less space than the first air-cooled tubes. While this machine penetrated thicker plates, it had no better sensitivity. As a matter of fact, it was slightly less sensitive than our old 200,000-volt air-cooled tube, within comparable plate thickness range, due to the use of a larger focal spot.

However, the investigation we had been carrying along, in collaboration with the General Electric X-Ray Corp., began to bear some fruit. After considerable experimentation with lead screens and other ideas, the General Electric Co. brought out an adaptation of the "Bucky grid" (Fig. 4), which, in a sense, saved the day for those of us who were deeply concerned with the reliability of heavy welds. With its aid we found that we could depend on the X-ray test up to 4 in. thickness of plate, but the

Fig. 2 — Oil-Immersed 300,000-Volt Tube. It had greater penetration b the radiographs were no sharper because the tube had a larger focal sp



time of exposure on this thickness, using the "industrial Bucky" and the 300,000-volt tube, was excessive.

This industrial Bucky combined grid, oscillating mechanism and film holder in one compact unit. We began to use it immediately on 2½-in. welds and over, and subsequently required its use on welds 2 in. thick. I believe that the development of this aid, at that time, was as startling and encouraging to us as the 1,000,000-volt tube is today. To demonstrate how the Bucky grid pushed back our frontiers at that time, I show in Fig. 5 two views of a very serious crack in a 3-in. weld. While this crack was so serious that it could be easily perceived on the negative taken without the Bucky, the difference in clarity is indicative of the fact that numerous cracks of a less order could occur in welds made day-by-day which could not be detected without it.

Meanwhile we purchased our third X-ray, a 400,000-volt oil-immersed outfit. As helpful as it was in improving the reliability of radiography, the Bucky grid is cumbersome and a great time consumer, in that the time of exposure is about six times longer. Extending the dotted time-thickness line for the 300,000-volt tube, with the Bucky (as shown on Fig. 6), you will note that, as plate thickness increases to 4 in., the time of exposure approaches 3 hr. This clearly demonstrated the need for higher voltage equipment, not alone to save time in lesser thicknesses, but to permit us to fabricate welded boiler drums above 4 in. in thickness.

The next development was a 400,000-volt oil-immersed outfit. On Fig. 6 we have plotted data for time vs. plate thickness for the 400,000-volt unit, with and without the Bucky, in dashed lines. You will note from these curves, which were plotted from our earliest data, that the 400,000-volt machine lifted our limit to material 5 in. thick. However, there have been demands for boiler drums of thickness up to 6½ in. or more. Due to the limitation of the X-ray test, the user has been forced to go to very expensive seamless forgings. At present, the forging capacity of the country is so taken up with other work that we are being forced to weld greater thicknesses than heretofore attempted. This year, we have been fabricating some boiler drums 5¼ in. thick. With our 400,000-volt machine and the use of the Bucky, it required 7½ hr. to take individual pictures of these weld seams. Therefore, you can appre-

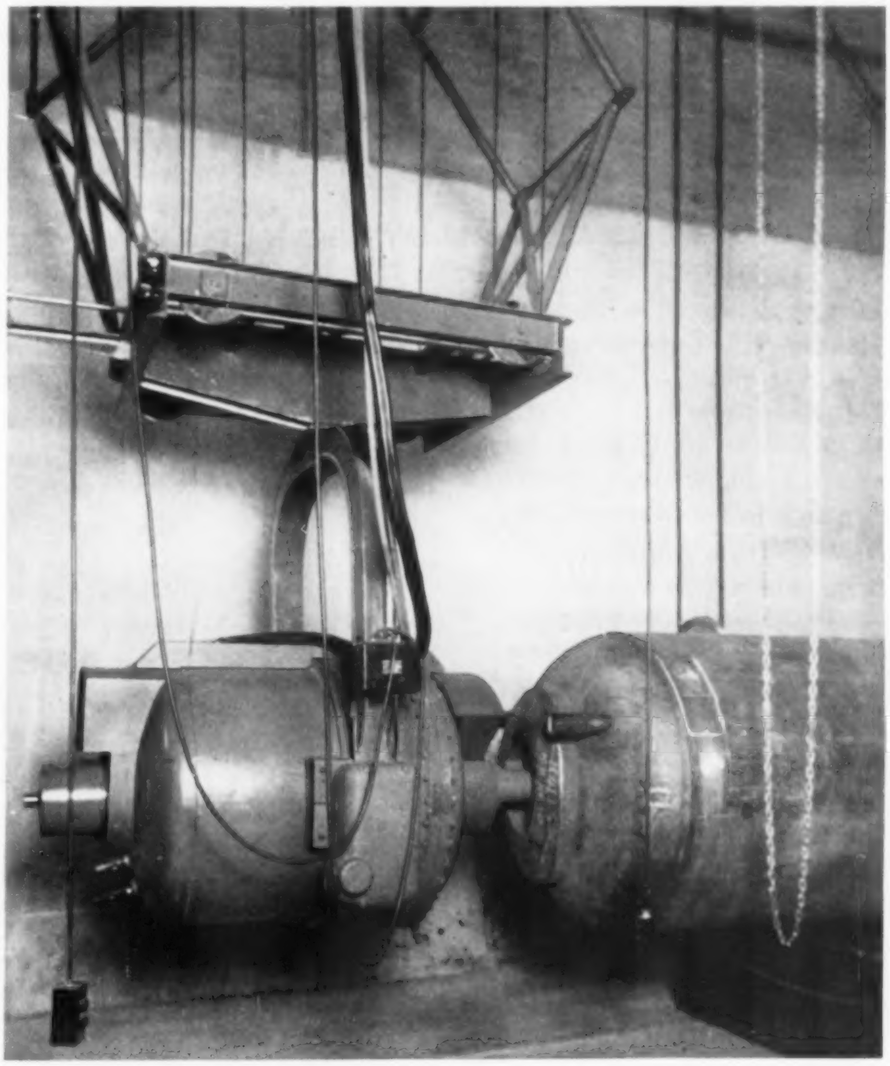


Fig. 3 — 1,000,000-Volt Tube and Universal Suspension. Focal spot is at end of 2-ft. tube projecting through end opening of boiler. Radiating in all directions, this position enables the entire circumferential seam between head and body to be radiographed at one time

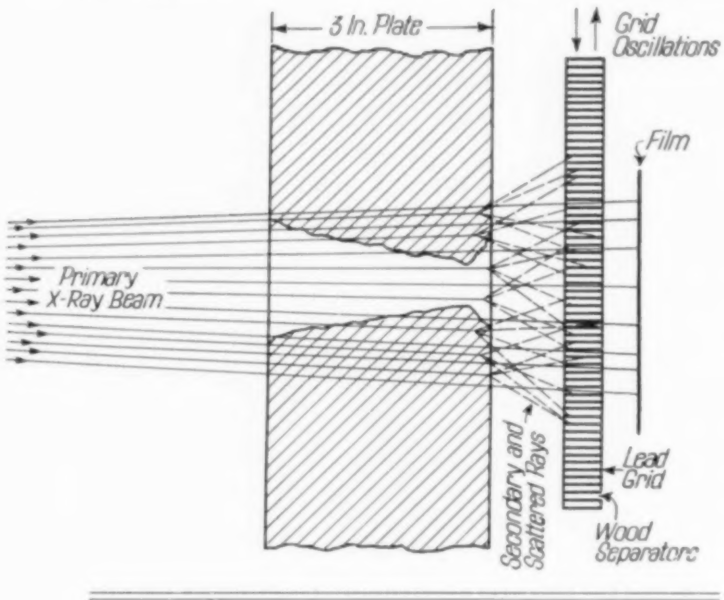


Fig. 4 — Bucky Grid Absorbs and Screens Out X-Rays Which Have Been Deflected From Their Normal Path. To prevent shadows of the lead grid, it must be moved back and forth constantly

ciate that we view the development of the 1,000,000-volt tube, which will take pictures of such thicknesses in 15 min., as progress of the first magnitude.

I would not presume to go into the technical details of this million-volt machine. We have had the apparatus such a short time that we have not yet worked out the niceties of procedure and technique. Figure 3 shows that the unit is assembled in a cradle, which is carried by an overhead crane. It can be traversed in three directions by the crane, and can be rotated on trunnions in the cradle from the vertical to the horizontal position. The equipment is housed in a room 21 ft. wide and 60 ft. long, surrounded with 18-in. concrete walls, carried to sufficient height to insure protection to all personnel. The control equipment is located in an anteroom connected with the main X-ray room by a concrete maze. The control room and adjacent dark room are further protected with additional lead. Large, rolling doors of concrete admit motor-driven trucks carrying the work. Power cannot be thrown on the X-ray tube until these doors are closed.

In the view shown (Fig. 3), the X-ray tube is shown located as for taking a picture of the circumferential weld seam. For a longitudinal weld the tube points downward and the film is inside the vessel; the apparatus of course is lifted to the proper focal distance. At present we are using films 32 in. long. Ample head room is provided, such that even longer pictures may be taken, if it develops that such is feasible. At the present time we are continuing with experiments along this line, together with other experiments to determine the desirable thickness of lead screen, the quantity of lead shielding necessary, and type of film. Intensifying screens and the Bucky diaphragm have been found unnecessary.

Heretofore, the method of radiographing girth seams shown in Fig. 3 has only been possible when using radium. With our old X-ray apparatus we were restricted to very short, individual pictures of circumferential seams. This was a real bottleneck in the production of thick-walled vessels.

Fig. 5 — Cross Crack in Weld in $2\frac{3}{4}$-In. Plate, Radiographed Without and With Industrial Bucky Grid. Many small defects otherwise invisible may be found when the grid is used

As I have mentioned before, one of the most startling things about this apparatus is time saving. This is shown in Fig. 6, a semilogarithmic graph with lines showing the exposure time for various thicknesses, for the various machines. You will note that the 400-kvp. performance is based on a 32-in. focal distance, and that the 1000-kvp. performance is based on 60, 48, 36, and 32-in. focal distance. You will further notice that the 1000-kvp. tube affords not only quicker exposure time, but a much better ratio between focus, work and film. Dr. H. H. Lester at Watertown Arsenal obtained optimum results with what he called the D/T ratio of 20, and recommended a minimum of 10. With the old industrial X-ray equipment, it was impractical to live up to any such minimum; with the 1000-kvp. tube, more desirable ratios can be used. The attached tabulation shows the approximate technique for 1000-kvp. industrial X-ray unit, for thicknesses varying from 1⅛ to 7 in., and for focal distances of 60, 48, 36, and 32 in. This technique is based on using ¼-in. lead filter between the film and cassette, and single film viewing. It is known that improvements can be made by using double films, but we have not yet developed full information concerning this procedure.

Were we not taking advantage of the opportunity to use a better D/T ratio with the 1000-kvp. machine, its performance as regards time of exposure, as compared to that of the 400-kvp., would be more striking. Comparisons drawn from Fig. 6 for thicknesses varying from 4 in. to 5¼ in., using the same focal distance of 32 in. on both machines, show that the time for 4-in. steel is cut to 1/35 required by the 400-kvp. machine with Bucky, and with 5¼-in. metal the

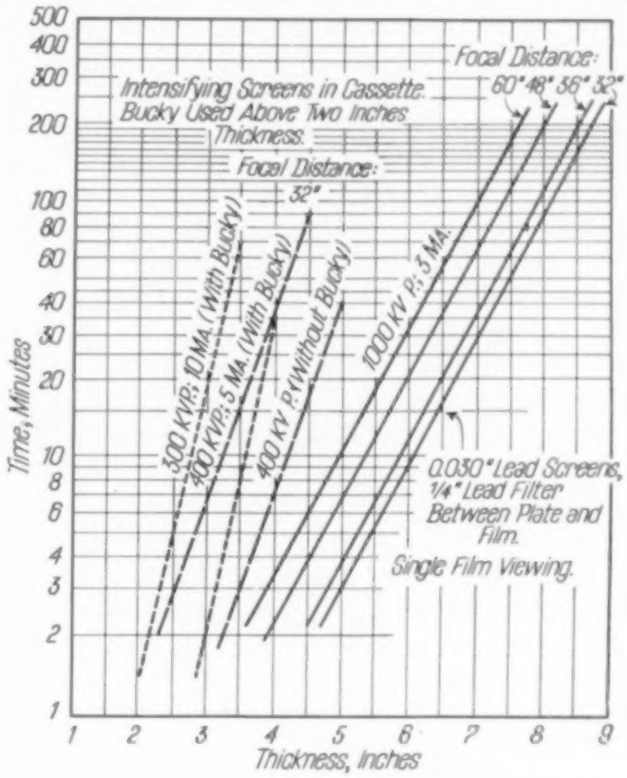


Fig. 6 — Approximate Time of Exposure and Thickness Limitations for Radiographing Steel Plate With X-Ray Machines of Increasing Voltage

time of exposure required with the 1000-kvp. machine is less than 1% of the time of exposure required with the 400-kvp. machine (4 min. vs. 7½ hr.).

Aside from the saving in time, the new machine is much more sensitive in detecting small defects in heavy plates. To demonstrate this, we have made a number of radiographs of a wedge test block (Fig. 7) developed at the Watertown Arsenal. It consists of two steel wedges 3 in. wide and 6 in. long, nested together so as to give parallel outside surfaces. One of these wedges varies in thickness from 0.281 in. on one end to zero on the other. In this wedge there are two rows of small holes, drilled on ½-in. centers, using a No. 50 drill (0.07 in. diameter). Also, extending for the full length of the wedge, are two vertical artificial cracks, varying in depth from 0.281 in. to zero. In the experiments we made with this test block, we

Approximate Settings for Million-Volt X-Ray Unit*

Thickness Plate, In.	Peak Kilovolts	Milliamperes	Minutes for Respective Focal Distance			
			60 In.	48 In.	36 In.	32 In.
1⅛	890	0.5	1.00	....	....	....
1½	890	0.5	1.50	....	....	....
2⅛	950	1.5	1.50	1.00	....	....
2½	950	1.5	2.75	1.75	1.00	....
3⅛	950	1.5	5.00	3.20	1.80	1.25
3½	950	1.5	6.50	4.20	2.30	1.60
4½	1000	3.0	6.00	4.00	2.10	1.70
5	1000	3.0	11.00	7.00	4.00	3.00
5½	1000	3.0	18.00	12.00	7.00	5.10
6	1000	3.0	35.00	21.00	11.00	9.00
6½	1000	3.0	58.00	37.00	20.00	16.00
7	1000	3.0	100.00	68.00	35.00	27.00

*Single film viewing; ¼-in. lead filter between film and cassette.

spread the cracks to a uniform width of 0.015 in.

In Fig. 8 are prints of exposure negatives taken of this wedge test block, both with the 400-kvp. machine using the Bucky grid, and with the 1000-kvp. machine without it. These were taken through the test block laid on a thick steel slab, and the wedge on the side remote from the film. Such films are almost impossible to print so they show much, but numerous negatives, appraised by skilled observers who did not know the exposure details, clearly show that the sensitivity of the 1000-kvp. machine at 6¼ in. thickness of plate is equal to the sensitivity of the 400-kvp. machine with the Bucky at less than 5 in. thickness. With further study and improvement in technique, there is little doubt but what this improvement will show up at even greater thicknesses. Further, we have tested the sensitivity of the new equipment by using another type of test block developed at Watertown Arsenal. This test block consists of a thin sheet of steel, ⅛ in. thick, in which there is a hairline crack of unknown, but varying depth. This type of fine defect constitutes a much more severe test than does the wedge test block. We were able to pick up the crack clearly, with both old and new equipment, up to 3⅛ in. thickness; but, in the case of the 400-kvp. machine and the Bucky grid, it was necessary to orient the grid line at an angle with the known direction of the crack. At 4⅛ in. thick the crack is discernible but beyond that it is definitely lost.

From the evidence already available, we can say without reservation that the development of this 1000-kvp. tube is an advancement of the first magnitude. For the welded pressure vessel industry, this testing equipment pushes back our frontiers beyond horizons we hardly expected to reach a few years ago.

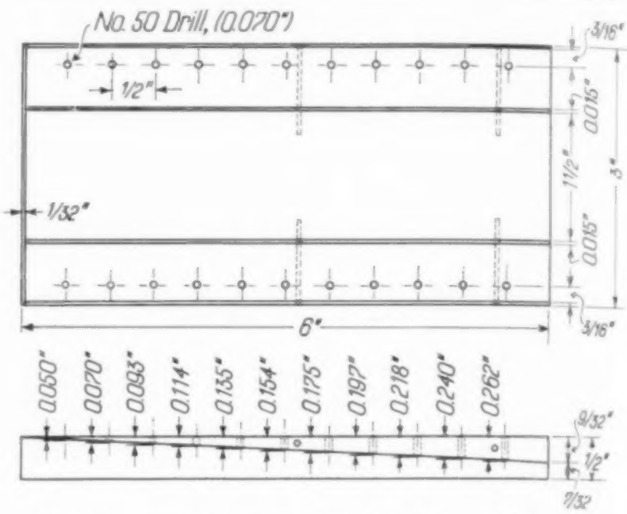
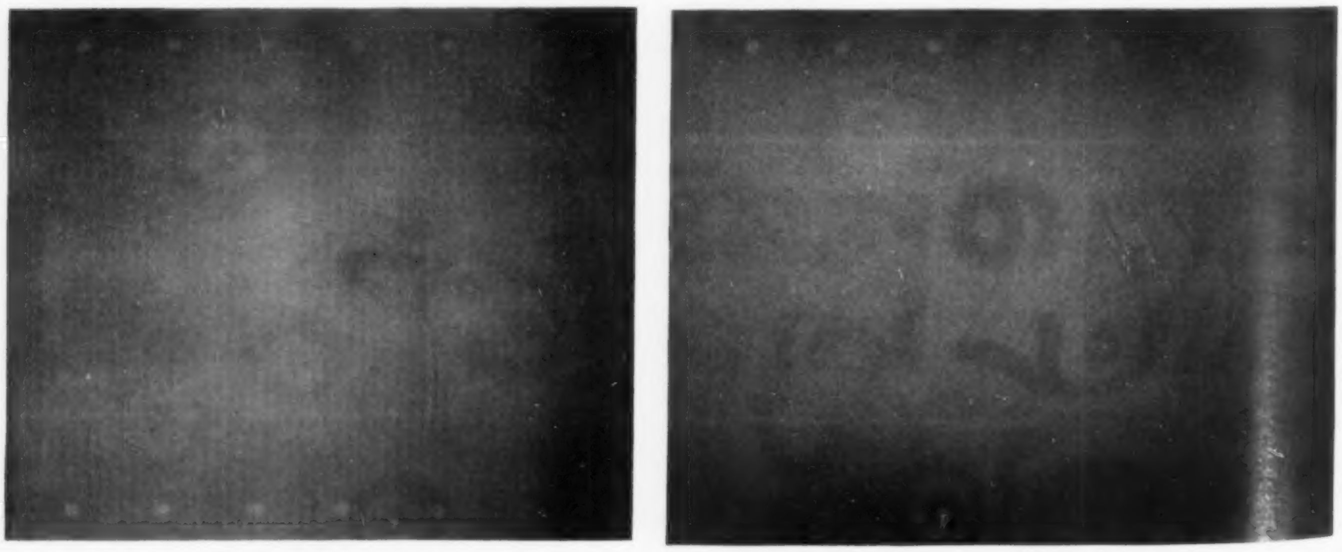


Fig. 7 — Wedge Test Block 0.5 In. Thick Containing 0.070-In. Holes to Varying Depths and Two Artificial Vertical Cracks 0.015 In. Wide, Varying in Depth From 0.281 In. to Zero

Fig. 8 — Wedge Test Block Exposures Showing Better Sensitivity From 1000-Kvp. Machine Than From 400-Kvp. Machine Using Bucky Grid



Wedge block on 4-in. steel
32-in. focal distance; 400 kvp.; 5.0 ma.; 55 min.

Wedge block on 4.75-in. steel
60-in. focal distance; 1000 kvp.; 2.0 ma.; 12 min.

Gravity and determination marked the National Metal Congress and Exposition. Numerous branches of Government service sent important men to tell the metallurgists, welders and wire men, not that they were doing fine, but that their laudable efforts were only at the beginning of an intensified program. Famines in aluminum and magnesium and impending shortages of other metals made paramount the problems of conservation and substitution. Record breaking numbers of technical discussions emphasized that research and development keeps pace with production — the problem is to direct it to armament.

METALLURGICAL INDUSTRIES IN THE DEFENSE PROGRAM

By MYRON WEISS
Publishers Consultant, New York City (Formerly Science Editor for *Time*)

IT IS NO NEWS to readers of METAL PROGRESS that an enormously large and enormously important industrial show is conducted annually in connection with the fall meeting of the ASM. October saw the 23rd such exposition. It was the biggest of its kind. Industrial exhibits covered three floors of Philadelphia's Convention Hall and Commercial Museum. Exhibitors numbered 335. Industrialists who registered numbered 40,452. Not a room in a decent Philadelphia hotel was vacant. Scheduled technical meetings numbered 79. The following quintain by HARRY HARRIS of General Alloys Co. might well have been the battle cry of the National Metal Congress and Exposition had the prosody of his exhortation to his colleagues been less impromptu:

The brain to plan, devoid of fear,
The steady hand of the engineer,
The will to do and the guts to dare,
Experience and science, sense —
That, men, makes National Defense.

More significant, this National Metal Congress and Exposition was the most solemn in its history. All the world, except the 250,000,000 in the Western Hemisphere, is at war. And these 250,000,000 are arming themselves against the threat of war. They constitute the free countries of the earth. The United States is their arsenal. The National Metal Congress and Exposition was the epitome of this arsenal.

Sponsors. Bulwark of the Congress and Exposition was, as customarily:

American Society for Metals, led by President OSCAR E. HARDER, assistant director of the Battelle Memorial Institute.

American Institute of Mining & Metallurgical Engineers. The Institute of Metals Division, led by Chairman D. K. CRAMPTON, director of research, Chase Brass & Copper Co.; The Iron and Steel Division, led by CHARLES H. HERTY, metallurgist, Bethlehem Steel Co.

American Welding Society, led by President GLEN F. JENKS, Colonel, ordnance department, U. S. Army.

Wire Association, led by President J. K. BEESON, vice-president in charge of sales, Pittsburgh Steel Co.

Scientific Sessions. Each sponsoring society provided a large body of learned and practical lecturers. To make way for the defense meetings in afternoon and evening, ASM concentrated its technical program in triplicate morning sessions, presenting no less than 70 topics for discussion. The American Welding Society was hardly less prolific with 64 papers

in 18 formal sessions. To say nothing of the informal breakfasts, luncheons, cocktails, suppers, and open doors, the faithful attendant had the choice of 41 technical meetings and 159 papers scheduled by the five cooperating groups, 18 general meetings, eight educational lectures and 12 panel discussions. Fortunately for the faithful attendant, the complete proceedings will be available in the respective *Transactions* and societies' publications.

National Defense cut across all the societies' programs. Two months before the Congress opened Director ROBERT E. MCCONNELL of conservation and substitution for the O.P.M. called representatives of these four societies to Washington, gave them the latest available information concerning supply and demand for strategic and critical defense metals. As result of that conference President HARDER and Secretary WILLIAM H. EISENMAN of the ⊕ and their colleagues arranged for eleven Philadelphia conferences on the conservation and substitution of important industrial metals. Each conference then had a leader, a panel of experts who discussed briefly his specialty and answered questions, and a summarizer. Their themes were:

1. Low carbon alloy steel (casehardening).
2. Manufacture of shell.
3. Problems in the fabrication of aluminum and magnesium base alloys for defense materials.
4. Higher alloy steels (oil quenching steels).
5. Copper and its alloys.
6. Stainless and heat resisting steels.
7. High strength, low alloy steels (weldable grades for pressure vessels, ships, rolling stock).
8. Inspection of metals for ordnance.
9. Alloy castings (steel and iron).
10. Bearings; problems of manufacture and use, conservation and substitution.
11. Molybdenum high speed and toolsteels.

These off the record discussions were vivacious and informal; SRO signs were hung up at several. For further notes by the Editor of METAL PROGRESS, see page 780.

Alumni. A notable aspect of the congress and exposition week was the number of midweek luncheons where alumni of U. S. technical colleges and universities gathered for gossip. Largest groups were from:

Carnegie Institute of Technology
Massachusetts Institute of Technology
Lehigh University
University of Michigan
Case School of Applied Science
Missouri School of Mines & Metallurgy
University of Minnesota
Yale University
University of Pennsylvania
Purdue University
Pennsylvania State College
Rensselaer Polytechnic Institute
University of Wisconsin

Honors. To succeed its President HARDER, the American Society for Metals installed its president-elect, Dr. BRADLEY STOUGHTON, dean of engineering at Lehigh University, chief of the O.P.M. tool section's heat treating equipment unit. Col. GLEN F. JENKS was re-elected president of the American Welding Society.

Immediately after the ⊕ annual meeting Past-President EDGAR C. BAIN (assistant to the vice-president of U. S. Steel Corp.) introduced Dr. ROBERT F. MEHL of Carnegie Institute of Technology, who then delivered the highly prized Edward deMille Campbell Memorial Lecture (see p. 759 for a brief account).

At the vast annual banquet of this American Society for Metals, outgoing President HARDER's voice grew exhausted simply introducing the long rank of industrial notables at the speakers' table. ALBERT L. MARSH, the inventor of the nickel-chromium wire fundamental to all electrically heated devices, was awarded the seventh Sauveur Achievement Medal. (Perhaps some will remember that his biography, printed in METAL PROGRESS in May 1935, instituted a notable series of articles on eminent men of metals.) JAMES P. GILL, Vanadium-Alloys Steel Co.'s chief metallurgist, shyly came to the rostrum to get his past-president's medal. Just as shyly, ⊕ Trustee MARCUS A. GROSSMANN, chief metallurgist of Carnegie-Illinois' Chicago District and a former Campbell Lecturer, came forward with his associates S. F. URBAN and MORRIS ASIMOW as Henry Marion Howe medalists.

The ⊕ banquet speaker, Foreign Correspondent WILLIAM L. SHIRER, disappointed the gathering by saying nothing about German industry and armament among which he spent a great deal of time as a journalist.

Before the Wire Association, KENNETH B. LEWIS, consulting engineer of Worcester, Mass., delivered the Mordica Memorial Lecture on "The Shape of Things to Come". C. W. GARRETT received the Wire Association Medal.

American Welding Society's medal for conspicuous contributions to the art and science of welding, given in memory of SAMUEL WYLIE MILLER, was presented to DAVID ARNOTT, chief surveyor of the American Bureau of Shipping. The Lincoln gold medal for the best paper pub-

lished by the Society was given to ROBERT H. ABORN of the U. S. Steel Corp.'s Research Laboratory. The 1940 Lamme medalist is former Harvard professor COMFORT A. ADAMS, now consulting engineer for Edward G. Budd Mfg. Co.

Discretion. Whereas the metallurgists, mining and metallurgical engineers, welders and wire men were quite candid *man to man* about their research and production, the factories in and around Philadelphia discreetly kept visitors out, unless they had mighty patriotic credentials. No National Defense secrets were voluntarily offered to unfriendly eyes and ears. It's just as well. Any plant visitations would have further congested the program!

The Exposition was more serene, just as informative, and less spectacular than previous expositions. Rapid delivery of equipment to new defense projects kept many exhibitors from sending large machines to Philadelphia for a week. In consequence, they had to use their minds and their mouths, instead of their index fingers, to tell customers what they had to sell. *Product* was in evidence, rather than raw materials or equipment.

This is a convention of useful ideas, more than an exposition of the American metals industry. Thus, it was apparent that welding may soon displace the riveting of tanks; tank bodies may soon be cast in one piece. Arcos Corp. showed pieces of tank armor with welded seams after ballistic tests. Projectiles that dug their way three-quarters through the plate penetrated but little further when they hit the seam squarely, neither did edge hits crack the joint.

Welding equipment dotted the exposition's acreage. *Resistance Welder Manufacturers Association* kept a voluntary staff of experts at its joint booth answering questions all week. Hair-thin sections can be butt-welded with ease. At the other extreme, welding of 7-in. armor plate is in prospect. Of special interest was *Harnischfeger Corp.'s* idea of mounting one small welding generator on top of another and operating them in parallel for the sake of heavy-duty welding. *Westinghouse* showed for the first time a new welder with a pre-set current adjustment along with an arc control. In its resistance welding controls, the vacuum tubes and other amazing parts suggest the stand-by services of an electronic engineer if it ever gets out of whack. GEORGE ("Whitey") MAURATH, this time, left his smirky mannikin in an outhouse and, master welder that he is, talked mainly of his science and art.

Realistic Teeming Scene by U. S. Steel

Republic Steel's CHESTER W. RUTH arranged the exposition's most spectacular tie-up with national defense. Besides stock exhibits of armor plate, gun parts and shells, there were anti-aircraft guns full size; Allison, Lycoming, Pratt & Whitney, and Wright aviation engines; a bomb sight; a half-tractor for hauling combat troops; a jeep. Tall civilians who got into the jeep wondered whether it would crack their knee caps when they jounced around in it.

Most eye-attractive of the exhibits — and that because of the colors inherent in their products — were those of the *Aluminum Co. of America* and of the brass fabricators — *American Brass, Bridgeport Brass, Chase Brass & Copper, Revere Copper & Brass.* Picture booths in colors!

The exposition was altogether too vast to remember as a whole or for all of its 335 displays. As you strolled through the aisles, stopping here and there, you made notes in your program. And after you got back to your home plant you were glad that you had noted, among others of course:

Army, Navy and *Air Corps* examples of their equipment. Ordnance officers were fine help to manufacturers with problems to solve.

American Gas Association's combined industrial gas exhibit; some furnaces and various types of burners in furious action. For a tidbit the association had a pleasant girl and a pleasant man making glass nicknacks.

American Rolling Mill induced the horror of an air raid by setting up an 8×15-ft. corrugated iron bomb shelter. Visitors entered the arched vault. Closed doors made the small room pitch dark and airless. Then a phonograph roared the sounds of an air bombardment into the ears of the queazy visitors.

Various departments of Baldwin Locomotive Works occupied a large consolidated exhibit. Alongside the *Baldwin-Southwark's* testing machines — well known to ASM'ers — was a vicious 30-ton tank with locked doors, but bristling with gun muzzles. *Great Lakes Steel Corp.'s* low alloy, high strength steel makes essential members of this brute.

Bethlehem Steel's complete spectroscopic laboratory attracted crowds of metallurgists.

Climax Molybdenum, sitting happy with one of the favorite and plentiful substitutive metals, set up a black and white lounge with three vice-presidents as senior hosts.

Copperweld Steel suggested how "Skill Counts" by means of two electrical "machine guns" which visitors could pom-pom at flying targets.

Beautiful effects were achieved with abrasive materials in showings by both *Carborundum Co.* and *Norton Co.*

General Electric built a small movie "House of Magic" in the shape of a huge electric furnace. Outside this were X-ray apparatus, industrial control devices, and a vacuum tube control for motors.

Jones & Laughlin Steel foxed a lot of visitors with a model layout of its efficient continuous sheet mill. They kept hanging around to see the miniature devices move. But the exhibit was simply and instructively a three-dimensional flow sheet.

Leeds & Northrup showed how their delicate, precise heat-control devices were making one pound of alloy steel do what three pounds did only a few years ago.

U. S. Steel had a magician entertain everyone who needed to sit down after wandering around the tremendous exposition. Technical U. S. Steel-men also gave the inquiring guests steel and manufacturing information.

Significance. Altogether this was a heartening National Metal Congress and Exposition. It demonstrated beyond all quibbling that American metallurgical industry is on the march for National Defense. Fun-makers were notably among those absent. The gravity of the present times was enhanced by the knowledge that even double our present efforts would be absorbed in tools to defend America.

National Defense Group Meetings

Notes by The Editor

IN SUCH a merry-go-round as described above by Mr. Weiss, one person can pay attention only to a small portion of the whole. Since the Editor had something to do with the organization of the group meetings, the following inadequate report is made of two of them for which he acted as summarizer, pinch-hitting for absentees.

These eleven meetings were organized on a plan unique to the ASM National Convention. They considered the conservation of various types of metallic alloys, and developed information concerning possible substitutes for materials commonly used in civilian industry, but scarce because of large demands for national defense and "lend-lease". In these meetings a panel of experts briefly discussed assigned phases of the general topic; this required about an hour, whereupon the audience was asked to comment, discuss or ask for further information. When this rapid interchange of views between the platform and the floor had proceeded sufficiently (in most cases taking another hour) a "summarizer" or co-chairman briefly restated the important facts that had been brought out. (Most of the prepared remarks for the meeting on stainless and heat resisting alloys were printed in the October issue, starting on page 675.)

General consensus was that these meetings were striking successes. Attendance ranged from 200 to 500, in at least two cases being limited by the standing room and the number who could crowd outside the door. Doubtless

this was due to the importance and timeliness of the topics; nevertheless it is amply proved that in them an interplay between speaker and audience was recaptured — that essential ingredient that has all but disappeared in the conventional technical program wherein a specialist discusses his specialty with such completeness and finality that the audience is sapped of any resistance.

High Strength, Low Alloy Steel

Colonel GLEN F. JENKS of the Ordnance Department, U. S. Army (and known to many ASMembers when he was commanding officer of Watertown Arsenal), was chairman of the conference on weldable grades of special steels for rolling stock, portable machinery, bridges and structures, ships, piping and pressure vessels. He was well fitted for the task, as the development of the light weight gun-mount for ultra-mobile artillery was sponsored by him. Other authorities were JOHN JOHNSTON, head of U. S. Steel Corp.'s Research Laboratory, and LEON BIBBER, the Corporation's welding expert; A. B. (GUS) KINZEL, chief metallurgist of Union Carbide and Carbon Research Laboratories; two men from Bethlehem Steel Co.'s staff — JONATHAN JONES, chief engineer of the bridge and structural department, and PAUL FFIELD, materials engineer of the shipbuilding division; J. J. KANTER, materials research engineer for Crane Co.; F. B. FOLEY, treasurer-elect ⊕ and superintendent of The Midvale Co.'s research department; MERRILL SCHEIL, metallurgist of A. O. Smith Corp.; and B. D. SAKLATWALLA, formerly vice-president, Vanadium Corp., and now consultant for Alloys Development Corp.

Since consideration was to be devoted to weldable steel, the general problem of weldability was given some consideration, even though it was handicapped by the circumstance that no workable definition of "weldability" has yet received approval or specific tests instituted. Much depends on such factors as the thickness of the material being welded, the welding method (amount of heat applied and its localization), and the design (ability to preheat, stress relieve, or heat treat). With these considerations in view, quite a latitude in chemical analyses is permissible. Some alloying elements endanger weldability greatly; others are relatively innocuous, and a rough approximation of their influence in order from those least desirable in weldable steel is:

C, P, S, Mo, V, Si, Cr, Mn, Cu, Ni.

(It will be recognized that this list would roughly parallel one showing the relative influence of alloying elements on the hardenability of steel. Indeed, one view is that hardenability is the opposite of weldability.)

Unfortunately those elements near the beginning of the list (the least desirable strengtheners of steels intended for welding) are the ones which are most plentiful. The most desirable elements are the scarcest; nickel is a constituent of many of the commercial steels under discussion, yet it was the first metal to be placed under restrictions and only about 1,000,000 lb. per month is now available for *all*

Medium Tank Made at Baldwin Locomotive Shops, and Exhibited in Great Lakes Steel Corp. Booth — One of Many Items Loaned by U. S. Army's Philadelphia Ordnance District

non-defense purposes; current news from Washington is that *no* vanadium will be available in 1942 other than for toolsteels and steels for Army, Navy and aircraft; chromium is a highly strategic metal imported over long sea lanes. While the 0.30% copper (more or less) added to these steels for corrosion resistance and strength is probably replaceable or not absolutely necessary, and while manganese must be conserved (see the notes below about manganese in shell steel), it is possible that enough copper and manganese can be wangled out of the really large uses to make our modest requirements of high strength steels.

It was pointed out, for instance, that probably 250,000 tons of low alloy, high strength steels went into non-defense construction in 1940, and this might be a measure of anticipated civilian consumption in 1941. Assuming that it contained 0.50% Cr on the average, the requirements (2,500,000 lb. of chromium) would use up 1% of the 250,100,000 lb. of chromium metal scheduled to be produced in 1941.*

In this conference, as in others, it was pointed out that (what with certain reserve stocks and growing production in the Americas) an extreme shortage in the critical metals, even when consumed at the present record rates, can come only from a shipping shortage. Even so the pressure of allocations will undoubtedly force metallurgists to consider steels using the materials we have in abundance, namely silicon, phosphorus, molybdenum, titanium, copper (and, hopefully, manganese). It was stated emphatically that a balanced combination of Cu, Si, Mo and P can make a weldable steel of excellent physical properties. George Comstock in an ⚙ technical meeting also described the high properties of steels alloyed with the combination copper, titanium and phosphorus. Whether the relatively small tonnage for true civilian consumption will warrant the rapid development of such steels commercially, is another point. Probably it will be decided on the basis that a strong steel made with non-critical alloys will save enough tonnage when substituted for mild carbon steels to warrant its production. Put in another way, if by spending a little chromium and manganese we can save a lot of steel containing somewhat less manganese, the net would be a profit in time and labor.

The way this works out in the essential railroad industry is as follows: A few months ago an official estimate was circulated that some 270,000 new freight cars would be necessary to handle the expected traffic peak. On car designs widely used and amply proved, a saving of four tons per car has been made by intelligent redesign with high strength wrought steel, and another ton may reasonably be saved by using alloy steel castings in trucks and draft rigging and by welding the body. Applied to all these cars we could apparently save at least one million tons of wrought steel, or the 1,400,000 tons of ingots from which it came — certainly a sizable saving in the raw materials (ore and coal) and in their mining and transportation.

If we are less grandiose in our expectations we might figure on no more than the 80,000 new freight cars per year that are necessary to maintain the present number in service. If their bodies were made of mild steel they would weigh 28,000 lb. each; if of high elastic steel 20,000 lb. The 80,000 cars would require approximately 1,550,000 tons of mild steel ingots, or but 1,100,000 tons if made of high tensile steel. To save this 450,000 tons of steel would require the following strategic alloys:

Alloying Element	Average Content	Deduct in Scrap or Common Steel	Net Use	Pounds Required	% of 1942 Supply
Manganese	0.85%	0.50%	0.35%	7,700,000	0.5%
Copper	0.30	0.15	0.15	3,300,000	0.1
Chromium	0.50	....	0.50	11,000,000	4.4

The 450,000 tons of steel ingots so saved amounts to about 0.5% of the expected 1942 capacity, and while we break even on the manganese, on the basis of the last column it would appear questionable whether we could afford to spend so much of our emergency chromium.

Another thing: Whether or not the entire saving could be realized would depend on the steel mills' ability to produce high tensile steels at the same rate as the plain carbon steels. The ingots require hot tops and longer time in the soaking pits (the soaking pit would undoubtedly be a bottleneck at the present moment) and are somewhat harder to roll. These factors are practically expressed in the mill cost, plus the

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*Another way of looking at it is not so favorable. Practically all of the chromium goes into stainless and heat resisting steels, toolsteels, S.A.E. steels and cast iron. Metal Progress last month (page 677) said that in 1940 only 3000 gross tons of low carbon 70% ferrochromium will be used in low carbon, low alloy steels and carburizing grades. Presumably as much might be allocated in 1941. This contains about 4,700,000 lb. of chromium, and the estimated need for weldable strong structural steels is over 50% of this.

ordinary extras for the high tensile steels, totaling about 45% more than mild carbon steel. Even if no extra expense is incurred in fabrication, one can see that the light freight-car body mentioned above would cost a little more to build than the heavier one. Economy (in case one is interested in such a prosaic thing) would come about in subsequent savings in hauling less dead weight around the country. This little matter of \$ and ¢ also explains the structural engineers' conclusion that carbon structural steel is adequate for static structures except in very long bridges and in the lower stories of high tier buildings — none of which are now being built. Only for traveling cranes of long span and structures on deficient foundations would the stronger steels be considered as economically desirable.

In shipbuilding — again an industry where it costs money to move the structure about — the urge to save weight is especially keen in warships such as destroyers. Here the weldable grade of manganese-vanadium steel has been widely used. A body of experience has been built up with it, and some serious difficulties would undoubtedly follow any rapid substitution. Notable economies have recently been effected by scrutinizing all the designs and using this strong steel only where necessary. Carbon-molybdenum steel is the favorite for high pressure steam equipment in the Navy as well as in power plants ashore, and fortunately no shortage is anticipated here.

In the field of heavy forgings both the relative and absolute amount of necessary alloying elements is small. While their inherent effect on the metal is also small, yet it is indispensable, the forgings not being heat treatable because of their very size. Present steel making and forge shop practices are the result of long experience, much of it acquired by trial and error before the days of scientific metallurgy, and substitutions would involve great risks. Fortunately there seems to be no danger that the small amount of alloys for these essential uses in heavy parts carrying high priority ratings will be restricted.

Use of high elastic limit steels of weldable grade is best exemplified in the military applications, and industry can well imitate what is being done in the 1941 designs of field artillery carriages, anti-aircraft and anti-tank gun mounts. Mobility is the prime essential of all equipment used by the field armies; a second essential is to increase the fire power. One can either save weight and increase mobility, or one can increase fire power using the same weight. An example of the first is the 3-in. anti-aircraft gun which used to weigh 19,000 lb.; now it is 16,100 lb. An example of the second is the 90-mm. anti-aircraft gun which is only 500 lb. heavier than the old 3-in. gun (76.2 mm.), yet throws a 70% heavier projectile to a 25% higher ceiling. Weight saving is likewise essential to the tank; its total weight is limited yet it should constantly have thicker and better armor. Low alloy steel with 105,000 psi. tensile strength is favored for bomb shells, as the stronger container increases somewhat the shattering power of the explosion.

Manufacture of Shell

One of the standing-room-only meetings considered the manufacture of shell. It was chairmanned by Prof. Arthur F. Macconochie, head of the department of mechanical engineering at the University of Virginia, and author of an extensive series of articles now appearing in *Steel*. Experts were F. G. Schranz, general manager of Baldwin-Southwark, makers of forging presses; Col. H. H. Zornig, now assigned to the office of the Chief of Ordnance, U.S. Army; Ben C. Brosheer, associate editor of *American Machinist*, and Alan Morris, research engineer of Bridgeport Brass Co., important manufacturer of cartridge cases.

Problems of shell manufacture are complex because the use of the product is so various. The missile must withstand the very high stresses at the moment of firing, and then do what it is supposed to do when it meets the enemy. The effects on the latter are three: First is the damage done by flying fragments — a very important matter even though shrapnel is *passé*. Next is the demolition of defenses or equipment, either near the open explosion or after the shell has penetrated protective armor. (Armor piercing shell is a highly specialized product, and is without the scope of this summary.) Finally comes the effect on the morale of troops near the target, and experience in the last war proved amply that the thin-walled French high explosive shell was far more terrifying than the thicker-walled missile used by the Germans.

The above considerations indicate that the metal in the shell must not fragment too much (thus cast iron is ruled out) yet be uniform enough in wall dimension and metallic prop-

erties so that it does not split on a plane of weakness but breaks into a number of fairly small pieces. It seems that the demolition and morale effects are little affected by the change in shell steel properties due to heat treatment; they are dependent upon the brisance of the bursting charge — that quality of a high explosive different from its strength or the degree of confinement, but related closely to the rapidity of its detonation.

At the present moment, the American Army uses shell which are designed from steel to have the following principal properties in the finished condition:

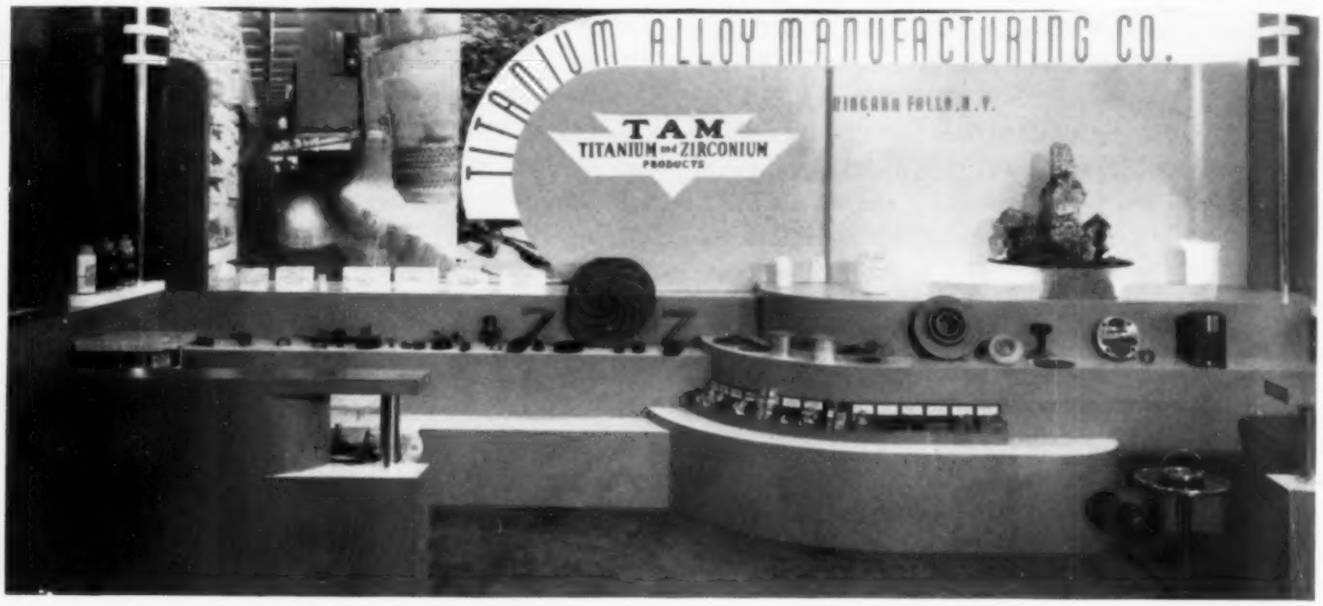
Yield strength	65,000 psi. minimum
Elongation in 2 in.	15% minimum
Reduction of area	30% minimum

In order to avoid manufacturing operations it is, of course, desirable to use steel that will produce these properties in the forged blank, not heat treated. Field artillery ammunition can be made in this way of X-1340 steels containing 0.35 to 0.45% carbon, 1.35 to 1.65% manganese, 0.045% phosphorus, and 0.075 to 0.15% sulphur (high sulphur to improve machinability). The high side of the specification is needed for 155-mm. shell in order to get the required properties in its thicker sections without heat treatment.

Avoiding heat treatment saves some time, labor and money, but has certain definite disadvantages: The thick shell base is rather too soft after slow air cooling; the internal stresses due to the cold nosing operation may cause trouble; and the machinability is but moderately good.

Owing to the relative scarcity of manganese and the tremendous quantities of shell steel required, the Ordnance Department is receptive to methods of manufacture that save this strategic metal. The required physical properties can be had in air-cooled forgings, but not so uniformly, in steels containing 0.45 to 0.55% carbon and 1.00 to 1.30% manganese. This for medium caliber projectiles; for 155-mm. the manganese must still be from 1.30 to 1.60%. A more drastic change is in the reduction of manganese to 1.00% and the heat treatment (oil quench and draw) of the rough machined and nosed forgings. Modern equipment for this, as developed at Frankford Arsenal, is described in Col. E. C. Bomar's article in October Metal Progress, page 509. (Questions made it evident that considerable confusion existed in many minds concerning the role of controlled atmospheres. It was emphasized that this did not affect the hardening and tempering reactions in the least. Its true function of preventing surface oxidation and damage is no new idea; the old-timer used the lead pot for the same laudable purpose.)

It is quite probable that the desirability of conserving one third of the manganese otherwise required will force the use of the 1.00% Mn steel, even at the large expense of hundreds of heat treatment furnaces. *(Cont. on page 842)*



THE 1941 CONFERENCE ON POWDER METALLURGY

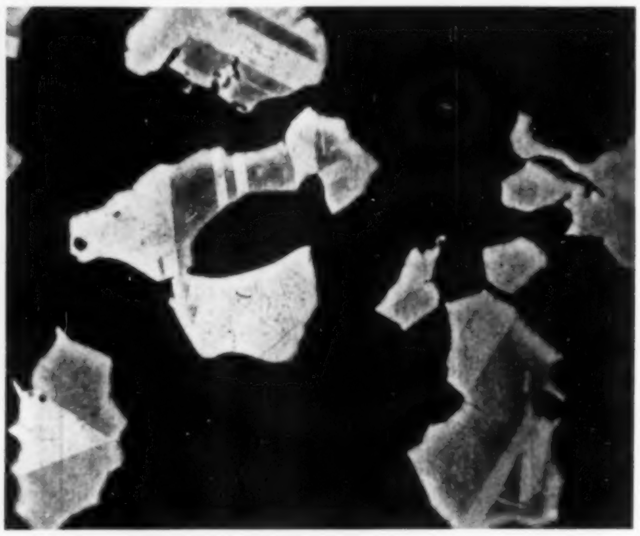
By JOHN WULFF
Associate Professor of Physical Metallurgy, Massachusetts Institute of Technology

LAST YEAR'S conference on metallic powders and their uses (reviewed in November's Metal Progress, page 665) was long on papers and necessarily short on discussion. This year's papers were purposely held short to permit extended discussion. For the 200 or so who attended the conference held at the Massachusetts Institute of Technology at Cambridge late in September the discussion seldom faltered. This may be attributed in large measure to the able chairmen of the various sessions as well as the effort of each speaker to present definitely new data or at least a new approach to older experimental facts.

The first day's program was primarily concerned with iron powder metallurgy. In the opening paper A. H. Allen, Detroit editor of *Steel*, after discussing various present-day processes for the manufacture of iron powder, presented the method devised by Tormyn of Chevrolet for hammer-milling steel turnings, cold pressing them, then heat treating the compacts at 1875° F. and immediately hot coining in water-cooled dies. The material is thereafter quenched, annealed, and finally coined cold to produce such parts as a lock-sleeve ring for a 3-in. ball bearing. The new product has been found stronger, more wear resistant and cheaper to produce than the conventional cast iron part. Discussion after this paper, led by Miss Frances Clark of Western Union Telegraph Co., was primarily concerned with the differences in the quality of iron powder produced in different ways. The consensus was borne out later in the meeting, namely, that some powders which exhibit excellent cold pressing characteristics do not necessarily have superior sintering or hot pressing characteristics. Of course, everyone would like a high quality powder for 2 to 3¢ per lb., yet an iron powder of consistently proper pressing and sintering characteristics is not obtainable at the present time below 8 to 10¢, if indeed that low.

In the next paper, the present reporter described a new method for making single crystal powder particles from 18-8 scrap by intergranular corrosion. The powder thus made has an apparent density of 3.6 to 3.9, a density of 7.2 after pressing at 33 tons per sq.in., and a density of 7.7 after 4-hr. sintering at 2300° F. in purified hydrogen. Hot coining in air after such sintering, then a short anneal at 1850° F. and a rapid cool, gives a product whose tensile strength, percentage elongation, and density are equivalent to those of cast material. Various applications in the cold-pressed and sintered state or when subsequently forged were mentioned. It was pointed out by commentators that cold-pressed and sintered articles of this powder would exhibit pit corrosion due to their porosity. This was admitted, yet the same total corrosion would be concentrated in but a few pits in denser material similarly exposed.

A paper by R. P. Seelig of Powder Metallurgy, Inc., on the molding of dense metal parts to compete in price with similar parts produced by machining proved to many the great value of proper die design. He described the difficulties in achieving structures of proper strength at sharp discontinuities in cross-section. Proper



18-8 Stainless Steel Powder Particles at 400 Diameters Made by Intergranular Corrosion of Heat Treated Scrap (John Wulff)

die design and pressing technique did not always suffice — indeed in one case the problem was solved by using a differently produced power of the same metal. A. J. LANGHAMMER of Chrysler's Amplex Division increased the value of the discussion by supplementing SEELIG's paper with data on much larger but somewhat simpler compacts.

Powder metallurgists at the meeting who will have no applications for the complicated pieces attempted by SEELIG, and who do not care to develop hot coining methods to improve ductility of even simple shapes, hoped that more designers would think and act as A. V. DEFOREST of Massachusetts Institute of Technology, who maintained that if simpler contours were employed in the design of machine parts, ductility specifications could be safely reduced.

To achieve maximum density and strength, SEELIG resorted to cold pressing, sintering, re-pressing and subsequent heat treatment. That such strength could be achieved in simple shapes by hot pressing was illustrated by C. G. GOETZEL of American Electro Metal Co. Pre-pressed compacts of various iron powders were subsequently hot pressed between 900 and 1500° F. in heated dies made of high speed toolsteel, and above 1500° F. in graphite dies. The former method gave complete densification of the powder when a pressure of 10 tons per sq.in. was maintained for 10 min. The use of emulsified graphite "aquadag" as a lubricant improved die life. In hot pressing, GOETZEL pointed out, pure and finely divided iron powders give better compacts than coarse and less pure powders, although the latter cold pressed better than the former. Although the low rate of production of hot-pressed parts, as well as high costs of die construction and maintenance, may prohibit practical application of these methods to iron powders, there was in the papers much information of basic value.

In the general discussion of methods to impart high physical properties of compacts, R. P. KOEHRING of Moraine Products Division, General Motors Corp., described the hot forging or hot coining of cold-pressed iron and iron-carbon compacts immediately after sintering. In this practice the compacts were heated at 2000° F. for 1 hr. before forging. The mechanical properties obtained from laboratory scale experiments on five different powders are given in the adjoining table. The hardnesses are somewhat below those mentioned by others who achieved after heat treatment a hardness of Rockwell C-58 to 63 and tensile strengths equivalent to S.A.E. steels of similar composition. Many laboratories are at present accumulating data similar to those presented by KOEHRING and ere long we should expect wider industrial

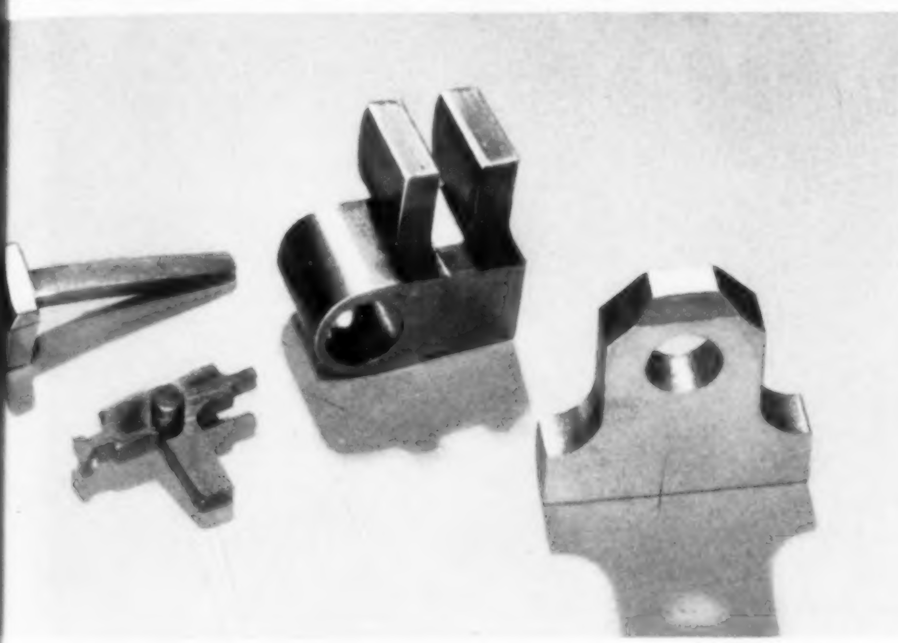
Pieces Tested After Cold Pressing of Powdered Iron, Sintering, and Forging (Koehring)

Raw Material	Density	Tensile Strength	Yield Point	Elongation	Reduction of Area	Rockwell Hardness
1	7.79	54,500 psi.	38,100 psi.	11% in 2 in.	13%	B-59 to 74
2	7.82	55,200	37,800	14	13	B-61 to 68
3	7.78	73,300	51,200	23	32	B-64 to 75
4	7.39	39,900	33,000	3	3	B-67 to 82
5	7.39	44,700	36,900	4	5	B-66 to 74

Raw Material No. 1. Steel turnings, hammer-milled and annealed
2. Decarburized steel powder
3. Decarburized steel powder mixed with 0.6% graphite powder
4. Iron powder made from reduced mill scale
5. Iron powder as in 4 but mixed with 0.6% graphite powder

application of hot coining of powder products to achieve better physical properties than is possible by cold pressing and sintering alone.

F. V. LENEL of Moraine Products, whose memorable paper last year was on oil-pump gears made from iron-carbon powder mixes, again presented a most original contribution. By heat treating previously sintered porous iron-carbon parts at 1075° F. in steam, the internal and external surfaces of the porous compact are coated with a thin impervious layer of magnetic iron oxide. Although the tensile strength of the material is below that of un-steamed material, the yield point in compression and the superior corrosion and erosion resistance of the new product have warranted numerous applications.



Four Interesting Parts Cold Pressed, Sintered, Re-Pressed Cold and Resintered by R. Seelig of Powder Metallurgy, Inc., to Achieve Maximum Physical Properties and Exact Sizing

EARLE E. SCHUMACHER of the Bell Telephone Laboratories, who was chairman of this session, maintained a fine balance between the scientific facts and the more practical aspects, so that all present benefited.

The three papers given the next morning were concerned with basic phenomena. P. E. WRETBLAD of the Fagersta Steel Works in Sweden, now in this country on a Scandinavian-American fellowship, considered the problem of sintering in general. He offered a precise definition of sintering as "the process in which solid bodies become bonded by atomic forces". No suppositions concerning temperature, pressure, phase changes, and the like seemed necessary to him, nor are included in the definition. To idealize his statements we may visualize sintering of two surfaces as complete when the original boundary becomes not a grain boundary but just another crystal plane. Fundamentally neither pressure nor temperature is required for sintering — only contact. Of course, WRETBLAD pointed out that pressure, heat, or both are required in practice to get contact and rapid atomic action, but such phenomena as recrystallization, grain growth, and bulk diffusion are concomitants of rather than prime requisites for sintering. He also believes that shrinkage may be viewed either as a surface diffusion process or as a plastic deformation process, the driving force in either case arising from surface energy differences of powder particles in contact. In the discussion of this paper it was brought out that unless heat treatment temperatures close to the melting point of the pressed compact are employed, porosity cannot generally be avoided. Indeed, for any particular powder and heat treatment there should be an "equilibrium pore shape".

Prof. PAUL H. EMMETT of Johns Hopkins University next gave an excellent paper on "Adsorption Isotherms of Micron-Size Powders". The method involves nitrogen, argon and such gases, and is readily applicable to particles less than 20 microns in size. A simple vacuum glass apparatus is used; after evacuation helium is first introduced and the adsorption isotherms subsequently are measured for the gases under study. With nickel, nickel oxide, iron, and copper catalysts, results were secured which are in remarkably close agreement with the surface area of fine solid particles calculated from shadow pictures taken with an electron microscope. In the case of porous particles, available surface is measured by these methods of Dr. EMMETT.

The last paper of that morning session was given by F. N. RHINES of Carnegie Institute of

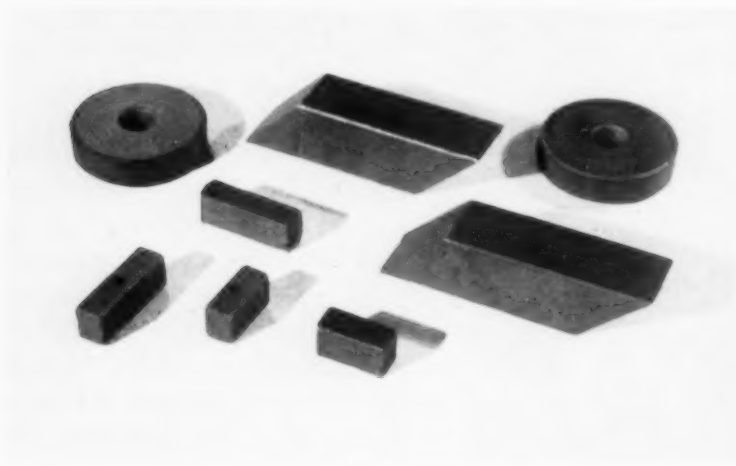
Technology. From electric conductivity measurements on copper-nickel compacts, heat treated in hydrogen, he formulated a theory of homogenization which on second reading promises to be of use to those who work with alloy powder combinations.

All three papers were vigorously discussed and your reporter (who happened also to be the chairman of that session) so enjoyed the arguments that he must refer you to the original manuscripts for further information.

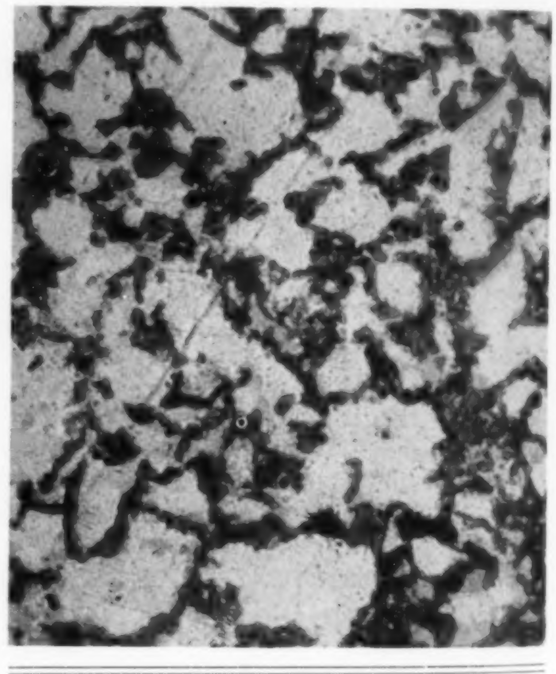
In the afternoon session, chairmanned by Fred P. Peters of *Metals and Alloys*, H. H. Hausner and P. W. Blackburn presented the first paper. It was on compound metals for the manufacture of electrical contactors. After various requirements and modes of testing had been delineated, photomicrographs were shown of molybdenum-silver, tungsten-copper, tungsten-silver, and tungsten-copper-nickel compacts made of constituent powders, including changes in structures obtained after heat treatment, forging, and subsequent heat treatment. In the discussion led by the chairman, F. R. Henzel of the P. R. Mallory & Co. and Miss Frances Clark of the Western Union Laboratories took an active part. Some disagreement appeared on the meaning of such terms as "sticking", "welding", "burning", "critical current".

M. F. Rogers of the Callite Tungsten Corp. continued his last year's paper on particle size measurements. This year he showed the advantage of selecting extremely fine particles in the manufacture of cemented carbide tools. The paper was well illustrated with photomicrographs as well as electron microscope pictures at 1400 diameters magnification. Maximum strength of cemented carbides was obtained with the finest particle size powders. The discussion of this paper brought out the higher rate of carbon diffusion and more rapid cementation when using extreme fines.

"Physical and Chemical Properties of Carbides After Final Sintering" was then considered in a paper by E. W. Engle of the Carboloy Co., which proved to be a most complete survey of the properties of cemented carbides, and included a discussion not only of tool material but also of cemented carbide tubing, spiral drills, springs, and the like. In printed form it should be the most authoritative compendium of data published to date.



Some Corrosion and Erosion Resistant Porous Parts Made by F. V. Lenel of Moraine Products. Iron and iron-carbon powders are compressed, sintered and then heat treated in steam at 1075° F. Micro at 250 diameters shows gray network of magnetic iron oxide coating the intercommunicating pores



The last paper at the meeting, given by J. Kurtz of the Callite Tungsten Corp., brought up a problem with which many industries are now confronted — what to substitute for nickel. In place of nickel alloys, Kurtz described substitutive iron-molybdenum compositions. The author compared the qualities of 5, 10, 15 and 20% molybdenum, 1% copper, balance electrolytic iron made from powder, with the qualities of alloys *(Cont. on p. 838)*

PERSONALS

Marcus A. Grossmann, director of research, Carnegie-Illinois Steel Corp.; **Morris Asimow**, manager, Central Metal Products Co.; and **Stephen F. Urban**, metallurgist, South Works, Carnegie-Illinois Steel Corp., have been awarded the Henry Marion Howe Medal of the for the paper of highest merit published by the Society during the preceding year.

A. H. d'Arcambal, a past president and consulting metallurgist, Small Tool and Gage Division, Pratt & Whitney Division of Niles-Bement-Pond Co., has been elected a vice-president.

Dallas Becker is now assayer-chemist for West Coast Mines, Inc., Winnemucca, Nev.

Albert L. Marsh, president and general manager, Hoskins Mfg. Co., Detroit, and inventor of the nickel-chromium resistors, has been awarded the Sauveur Achievement Award of the for outstanding contributions to the field of metallurgy.

Stephen D. Garst, formerly in the Bureau of Ordnance, Navy Department, is now assistant technical editor for the American Foundrymen's Association, Chicago.

Henry F. J. Wilmot has been promoted by Carnegie-Illinois Steel Corp. from contact representative, Stainless Bureau, Metallurgical Division, Chicago District, to assistant to the chief inspector, Gary Works.

Martin F. Richter, formerly with the Perfection Tool and Metal Heat Treating Co. of Chicago, is now in charge of sales and consulting, for California Steel Treating, Inc., of Los Angeles.

W. C. Heaslip, formerly with the United Steel Corp., Canada, has accepted a position as chief metallurgist with the associated American company, Edge Moor Iron Works at Edge Moor, Del.

Promotions by LaSalle Steel Co., Chicago: **Maurice N. Landis**, from chief metallurgist to manager of metallurgical and research division; **A. Frank Golick**, from special sales representative to assistant general manager of sales; **H. N. Landis** to assistant manager of metallurgical engineering.

C. A. Heil, district sales manager for the Carpenter Steel Co., Cleveland, has announced his retirement, and will be succeeded by **James S. Bailey, Jr.** of the Cleveland sales staff.

H. F. Robertson has been appointed district manager of the New England office and warehouse of Jessop Steel Co. in Hartford, Conn.

MORE CHIPS PER MINUTE

with CIRCLE "C" SUPER HIGH SPEED STEEL

No matter what the unit of time—minute, hour, or day—the *true measure* of a cutting tool's effectiveness can be judged by the *net* amount of metal it removes in a given period.

CIRCLE "C" Cutting Tools are constantly demonstrating their capacity to work at 25% faster machine speeds, with greatly increased cuts and feeds and far fewer shutdowns for re-grinds on the hard and heat-treated alloys used in production of *shells, aeroplane engines and other armament.* Thus, this high cobalt-tungsten Super High Speed Steel, distinguished in a peacetime economy for its prodigious chip removing ability, now occupies a unique place among steels in Defense industries. *Although a tungsten steel it actually conserves tungsten through greater production as compared with other tungsten high speed steels.*

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PERSONALS

Transferred by The Linde Air Products Co.: **H. T. Herbst** ⊕, development engineer, from the development laboratory at Newark, N. J., to the district sales office in Los Angeles.

S. B. Knutson ⊕ is now plant metallurgist for McQuay-Norris Mfg. Co., St. Louis Ordnance Management Division, St. Louis Ordnance Plant.

R. J. Hafsten ⊕ has left the metallurgical laboratory of Carnegie-Illinois Steel Corp., and is now employed as metallurgist for Firestone Steel Products Co.

Norman P. Goss ⊕, formerly with Cold Metal Process Co., has been appointed a research engineer for American Steel & Wire Co., Cleveland.

Philip C. Rosenthal ⊕, formerly on the faculty of the department of metallurgy, University of Wisconsin, has joined the research staff of Battelle Memorial Institute, Columbus, Ohio.

Albert P. Miessler ⊕, formerly assistant to J. E. Robinson, superintendent of metallurgy, Chicago office of International Harvester Co., has been transferred to the Richmond, Ind., Works, where he becomes plant manager.

Thomas C. Ford ⊕, metallurgical engineer with Electro Metallurgical Co., has been given a leave of absence to become associated with the Office of Production Management.

Robert H. Aborn ⊕, Research Laboratory, United States Steel Corp., has been awarded the Lincoln Gold Medal of the American Welding Society for the paper which contributes most to the year's development of welding.

Stanley Reider ⊕, Rensselaer Polytechnic Institute, '41, is employed by the Crucible Steel Co. of America, Harrison, N. J., as engineer in the metallurgical mill control of high speed steel.

Donald E. Stingel ⊕, Carnegie Institute of Technology, '41, is employed as a student in the Alloy (West Virginia) plant of the Electro Metallurgical Co.

Oscar Nerenberg ⊕ has been employed by A. O. Smith Corp., Milwaukee, as research engineer with the welding research laboratories.

John K. Hambright ⊕, formerly sales and service engineer for Brown Instrument Co. at Providence, R. I., is now research engineer at the new Plastics Division of Briggs Mfg. Co., Detroit.

Gordon H. Gillis ⊕, formerly at the Duquesne Works of Carnegie-Illinois Steel Corp., is now a metallographer with the McQuay-Norris Mfg. Co., Ordnance Division, St. Louis, Mo.

SOME TESTS ON QUENCHING OILS*

By T. F. Russell

EXPERIMENTS have been carried out along lines suggested by SPEITH and LANGE to find a simple standard quenching test which would indicate the capacity of the oil for abstracting heat from a body and at the same time yield results that could be correlated with other physical and chemical measurements. In this work a 1-in. silver sphere carrying a platinum thermocouple (0.006-in. wires) was heated in a vertical furnace from which it could be dropped into the oil to be investigated. As soon as the ball reached the surface of the oil, a photographic drum shutter was automatically raised on a film focussed on the galvanometer mirror, and the time-temperature cooling curve was recorded. The oil was held in a cylindrical pot 5¼ in. in diameter, exactly 2 liters being used for each experiment. Care was taken that the ball fell exactly to the center of the oil. When the ball had cooled, lines at regular temperature intervals were produced by double exposure on the photographic record by a potentiometer, to calibrate the curve.

With the thermocouple junction at the center of the ball the cooling curves are readily reproducible to a high degree of accuracy. With the junction at the outside of the ball repeat tests agree well, but the cooling curves vary appreciably with the position of the couple on the surface of the ball. Tests on a small cylinder of a low nickel-chromium steel and on a sphere of austenitic nickel-chromium steel, with the thermocouple at the center in both cases, showed appreciable differences on repeat tests (later found to be due to the differences in the nature of the scaled surface).

For each of the eight oils tested a fairly well-defined point was found at which the cooling rate changed appreciably. These "characteristic" points occurred at temperatures from 920 to 1180° F. Above this the cooling rates did not vary appreciably, one oil to another. Below the characteristic temperature the cooling rate increased and attained its maximum value, generally over the range 950 to 750° F. *(Cont. on page 806)*

*Abstract of Second Report of the Alloy Steels Research Committee, British Iron & Steel Institute, page 283 (1939).

TIME was, when all pyrometer galvanometer suspensions were merely wisps of ordinary metal held in crude soldered end-clamps. Acid atmosphere ate the metal . . . ends sheared off on the square edges of clamps . . . breakage was accepted as a necessary evil.

Even though it is the smallest, least conspicuous assembly in a Foxboro Potentionmeter Instrument, Foxboro engineeers were not content with this traditional galvanometer suspension. They engineered this detail, too, like a major part!

Gold suspensions were adopted to defy acids . . . with spot-welded instead of soldered ends. Smoothly-crowned end-brackets were designed, to give shear-free, "rocking-chair" snubbing action for these tiny gold "whiskers". Suspension life was indefinitely prolonged!

This is what we mean by Foxboro Creative Instrumentation . . . instrument engineering that carries original, progressive development work to the last detail of design, construction and practical application. By providing precise indicating, recording and control of hundreds of operations, it is enabling manufacturers to obtain more productive and dependable results.

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QUENCHING OILS

(*Continued from page 800*)

A "kink" in the cooling curve did not always occur when the steel cylinder or the austenitic steel ball was used. With the steel cylinder a definite kink was obtained only when the surface of the ball was freshly polished. The effect of tarnishing of the surface was naturally much less for the austenitic ball, and a small kink was obtained with one oil.

Sperm oil gave appreciably faster rates of cooling than the mineral oils over all ranges of temperature down to 600° F. The cooling rate in the range 1100 to 950° F. for the old oils is approximately double that for the new oil on its first quench. No satisfactory correlation between these quenching tests and chemical or physical properties has been obtained.

The initial temperature of the oil, if below 200° F., had little effect on the *rate* of cooling. However, for one oil of low volatility the curves agree with what might be expected if the cooling rate at any time is proportional to the difference in temperature between the ball and the oil.

The quenching curves for the silver ball can generally be divided into three well-defined sections:

1. A fairly rapid fall in temperature of about 50° F. per sec., which does not vary a great deal for different oils. This portion of the temperature-time curve is usually a straight line, but in some cases it may be slightly curved. It continues as far as the "characteristic point".

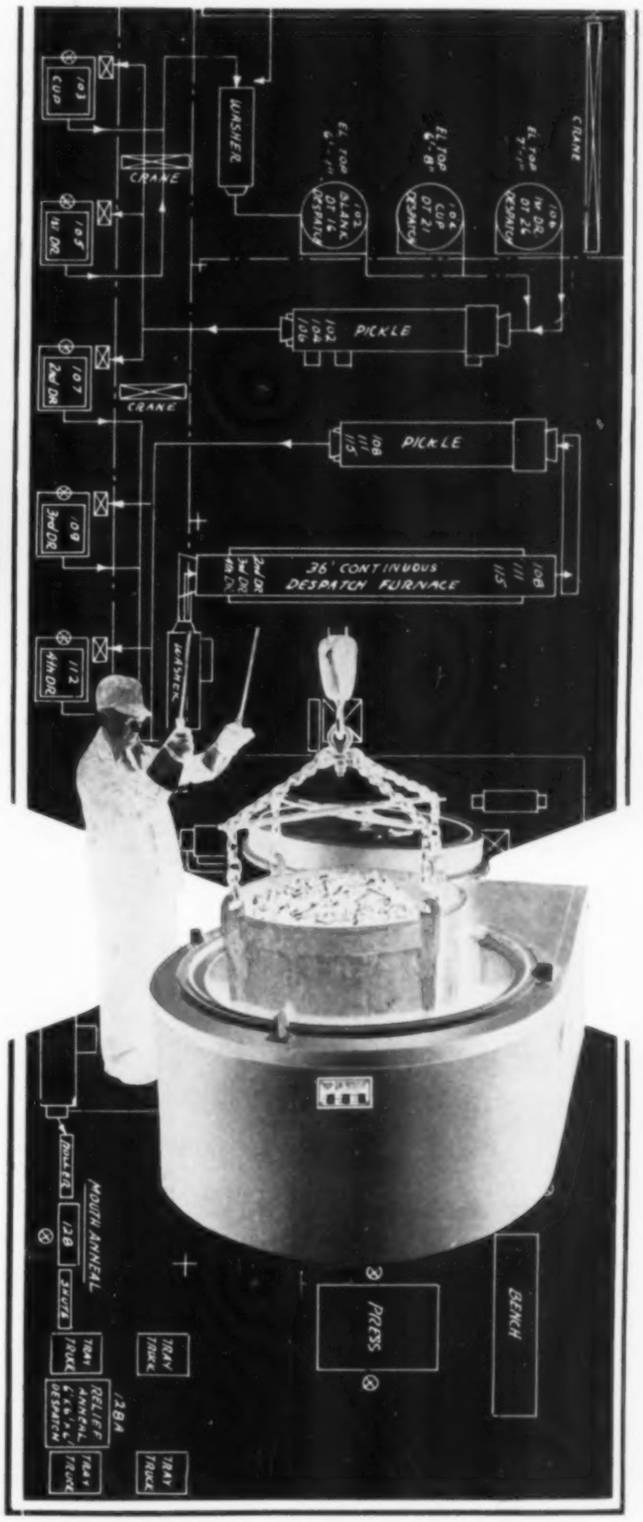
2. Then comes a short period of very rapid temperature drop, at a speed often amounting to 150° F. per sec.

3. Finally is reached the ordinary cooling of the body in the oil at an exponential rate which varies considerably for different oils.

The presence of a well-marked change in the rate of cooling at both the center and outside of a silver ball has been attributed to a change in the mode of heat transfer from the ball — that is, from radiation through a vapor film formed during the first period to direct conduction and convection of the oil after the vapor jacket has disappeared. On a smooth surface the thickness of the vapor film will be gradually reduced until the liquid contacts the hot surface, whereas on a rough surface the vapor film will tend to be formed repeatedly and driven away irregularly over the whole surface. This will reduce the abruptness in the change in the rate of cooling, so that there may be no sign of any kink on the cooling curve for the outside of a scaled steel test piece.

A DESPATCH system for heat treating 4300-20mm. shell cases per hour is shown at the right. It carries through from brass blanks—through draw presses and Despatch annealing furnaces—and finally through a Despatch stress relief furnace. The Despatch furnaces and other equipment arrangement provides material handling efficiency with minimum floor space. In this plant, Despatch furnaces were chosen because they provide speedy, accurate heat treating results together with increased production. Despatch furnaces are also performing perfectly for tempering and drawing of projectiles and shot, and on other armament projects where efficient, accurate heat treating in the range of 275°F. to 1250°F. is required.

For those interested in the details of the layout illustrated, Despatch has available copies and will mail upon request. Whenever you require new heat treating equipment to increase your defense production, call a Despatch engineer to make a survey and submit his recommendations.



Despatch furnaces used in above layout for heat treating 4300-20mm. brass shell cases per hour.

1—Despatch DT-16 Pot Type Gas Fired Furnace, 1200°F.
1—Despatch DT-21 Pot Type Gas Fired Furnace, 1200°F.
1—Despatch DT-26 Pot Type Gas Fired Furnace, 1200°F.
1—Despatch Continuous Conveyor Annealing Furnace, 1200°F.
1—Despatch Stress Relief Furnace, 500°F.

Write for New Bulletin No. 81-F.

You will find it a helpful guide for heat treating ferrous and non-ferrous alloys with many interesting photographs of Despatch furnaces in action and with careful attention given to material handling.

DESPATCH
OVEN COMPANY MINNEAPOLIS, MINNESOTA

BOUNDARY LUBRICATION*

By Otto Beeck

IF TWO lubricated surfaces are sliding over each other under conditions of high pressure and low speed, no truly fluid film of lubricant can exist between the sliding surfaces. The term "boundary lubrication" has been widely adopted for this condition, but the best criterion for this state is that the coefficient of friction is independent of viscosity and of the sliding velocity. The term "oiliness" indicates the lubricating value of an oil under these conditions.

Plastic deformation takes place at the local points of load transfer and the real area of contact between flat surfaces is proportional to the normal load. This gives an explanation of the old law of AMONTONS (1699) which states that the tangential frictional force is directly proportional to the normal load. It also explains the other observation of AMONTONS that the friction is independent of the macroscopic area of the surface.

Lubricating the surfaces under boundary conditions does not prevent the surfaces from reaching temperatures of 1100° F., and it is evident that breakdown or decomposition of the boundary film must then occur.

It has been assumed that friction takes place between monomolecular films of lubricant adsorbed on the solid surfaces. However, tests indicate that a mono-molecular film would not stand up under the very high temperatures produced at the points of contact, but a film of fatty acids seven mols thick seemed to wear indefinitely.

The first clean-cut case of boundary lubrication was obtained by BEARE and BOWDEN using a flat flywheel with a spherical rider. The flywheel was set in motion and its deceleration was observed by plotting the angular velocity against time. With highly polished steel surfaces and fluid lubricants such as octyl alcohol, a straight line was obtained. Viscous and oily lubricants, however, always showed that their coefficients of friction depended upon velocity. But it has been observed that, even with such lubricants in the flooded state, true boundary conditions can be obtained.

If the coefficient of friction is plotted against velocity the curve bends over sharply at certain critical and easily repro-

(Continued on page 814)

*Abstract of "The Physical Aspects of Boundary Lubrication" by Otto Beeck, *Journal of Applied Physics*, July 1941, p. 12.

E FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

GA X-ITE GA Q-ALLOYS GA X-ITE GA Q-ALLOYS

GRATULATIONS to A.S.M., Bill man, Ern Thum, *et al*, for their TANDING Co-ordination of A.S.M. ical Sessions, *Metal Progress*, the Exposition, and their OPM work to S. DEFENSE. The Show TOPPED ers, all work, no play. Many a Sur-Package for Anxious Adolph was d up at Phila., even Georgie Jessel ophie Tucker in "High Kickers" a Metallurgical Matinee Wednesday. -five years and blank husbands back ertained Sophie and current spouse Westphal at the D.U. House in Madi-phie eating three plates of beans and ccharine tablets, the night before we d to "Make the World Safe for De-y". Later delegating at the caucus f the American Legion at St. Louis urned our dead and beat our s" into flivvers. The scrapped fliv-med Japan.

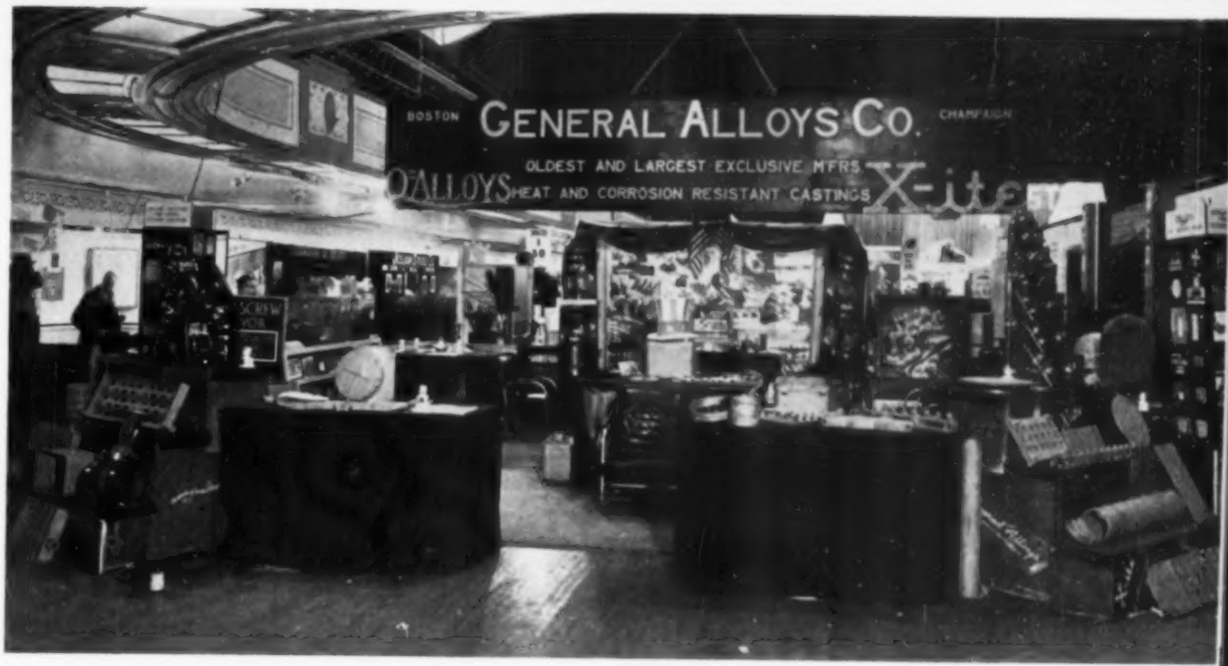
OUNG lady Chemist—lubricated ex- with "B&B" by Sam Kite of Houghton & Co.—claims to have ed "NYLON". "Just an abbrevi-, says she, "N-utz to Y-ou L-ousey Nipponese".

RLES WESLEY, re-elected Pres. of OMMERCIAL HEAT TREATERS, Party at Bookbinders' Lobster Loft "Opening Event" of the Phila. Nothing remained unopened. Charlie d his National REP as a "Stop-Toastmaster", producing U.S. Sen-iley of Wisconsin, Presidential Pine and emphatically NO stuffed-shirt, ker. A Smash-Hit! (Sen. Wiley slips one, "We hope to elect Charles as Republican Lieutenant-Governor onsin". Charley, like other Modern, Commercial Heat Treaters, is d with General Alloys Q-ALLOY and ntainers, hearths, and furnace parts.

you been startled, or dismayed, by onfessions" now required by law on s of food products? Take good old "A-1" Sauce for instance. 'Tis om Tomato Puree, Orange Marma-isins, Onions, Garlic, Malt, Vinegar, Salt, Tragacanth, Spices, and Flavor-That's an alloy that would even tax enuity of a steel foundry melting alloy scrap for DEFENSELESS (We're going to tip the kitchen nto the Bendix and put "PrestO-" on the Curb Market.)

with the contents noted, it's 100 t it STILL TAKES BRAND'S to "A-1" Sauce. You'll gather our if you've ever sampled some of Made to Q-Alloys Formulae" sub-alloy.

LTIVATED corn, even in Cham-County, Illinois, yields only 20 bu. . One cultivation boosts yield to 35 cultivations 50 bu. and up. The VATION breaks the top CRUST, light and air, promotes growth. A R CULTIVATOR—not a good 5¢ s the Great National Need. Hitler's rnerstone for German re-armament TRIPLE the number of APPREN-



PHILADELPHIA METAL SHOW AIDS U. S. DEFENSE GENERAL ALLOYS LARGEST CASTING EXHIBITOR FOR 22nd CONSECUTIVE YEAR.

No higher compliment could be paid to this organization than that bestowed by the many outstanding Men of Industry who have sought our Engineering counsel in their DEFENSE Heat Treating problems. It has been a great privilege to work with you Men of A.S.M., through nearly a quarter century, maturing that fine friendship and confidence which now forms the solid basis on which we stand together in U.S. DEFENSE.

Now it can be told.

WITH our plant running three shifts, General Alloys Company's UNFILLED ORDERS went up SEVEN HUNDRED PER CENT in 60 Days! 100% expansion had ALREADY been accomplished! OPM, U.S. Navy, Army Air Corps, were making insistent demands, extending every co-operation. Air Engine Program, certain Navy requirements, and other VITAL DEFENSE items *had* to take precedence, throwing our production cockeyed. NOW we have COMPLETED our SECOND expansion of facilities, have greatly reduced, and are steadily reducing our backlog, have equipment on hand and on order which should enable us not only to take care of our Customers' present and near future requirements, but to plan replacements as anticipated, and carry a stock of "SPIRALINK" and other G.A. Designs. Yea, verily, we have been "Sweating Bullets", working the clock around and doing our best. Conscientious management demands the BEST alloys, and PROVEN ENGINEERING for DEFENSE. General Alloys leadership in Design, Metallurgy, Foundry Practice has never been seriously questioned. We, like the LEADERS in other lines, had to pick up the DEFENSE LOAD FIRST. WE have shouldered that load, AND ARE UNDER WAY FOR THE BIGGER LOAD AHEAD. We are humbly grateful for your FORBEARANCE.

H. H. HARRIS

PAL JOEY

HIGH in the rolls of "Defenders of Democracy" stands Kristian A. Juthe, Pres. of American Electric Furnace Company. Eighty-eight of their CARTRIDGE CASE ANNEALING FURNACES, turning out MILLIONS of Rifle Shell Cups per HOUR, have been running behind the RUSSIAN lines facilitating aerial export of lead toward Germany. "K.A." as he is known to Heat Treaters everywhere "Spark-Plugged" the U.S. Rifle program in the last War. (Those furnaces are all equipped with X-ite internal-spiral retorts by G.A. Co.) We have another confession. When the Russians couldn't get good STAINLESS STEEL SCULPTURE from Germany, some years back, General Alloys took the job, including the Original Sculpture, and delivered the "ETERNAL METAL" bas-relief of JOSEPH STALIN which was hung in the KREMLIN. The first sizable bas-relief ever cast in S.S. this G.A. CASTING will rank among the great castings in HISTORY. G.A. Foundry practice was a WORLD STANDARD when many present "alloy manufacturers" were making steel castings to quarter inch tolerances.

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

BOUNDARY LUBRICATION

(Continued from p. 808) duced velocities, whereupon the coefficient of friction becomes constant. Ricinoleic acid, the main constituent of castor oil, does not show this effect. Neutral or white oils likewise do not show the effect at low velocities. The adsorbed layer of long chain polar molecules seems able to induce a so-called wedging effect which allows an early transition from the boundary state into one with lower coefficients of friction.

Rapid fluctuation of the surface temperatures occurs under boundary lubrication conditions, and a frictional fluctuation called "stick-slip" (see METAL PROGRESS, April 1940 page 435). The exact behavior depends on the combination of metals, particularly on their melting points and on the lubricant. In case of dissimilar metals the fluctuations are quite regular. The surface of the rider sticks to the moving bottom plate (it is, in fact, welded to it) and moves with it until, as a result of the increasing force which wishes to keep the rider in its original position, a sudden and very rapid slip occurs. Simultaneously with this slip there is a sudden temperature flash which produces the next welding, and so on. Surfaces lubricated with straight mineral oils behave in the same manner. Long chain fatty acids, for instance, may prevent the stick-slip and allow continuous sliding to take place. But not all boundary friction occurs with this type of stick-slip.

No correlation is found in practice between the coefficients of friction and wear with various oils with and without addition agents. Under moderate conditions the coefficient of boundary friction varies but little with pressure, temperature, and material of both lubricant and surfaces. Steel balls were electroplated with a very thin and uniform copper plate, whose wear characteristics were found to be similar to those of iron run until the track on the upper rotating ball was worn through to the steel. Under these conditions long chain polar compounds prevented very little wear, but other known additions, like tricresyl phosphate, reduced the wear by a factor of about five.

The action of the last mentioned compound is essentially that of chemically polishing the surface. The formation of low melting metal phosphide alloys plays a major role. The process of polishing is mainly influenced by the relative melting point of the polisher and the solid; the relative hardness is comparatively unimportant.

A white oil whose wear reduction factor was raised to five by the addition of 1.5% tricresyl phosphate showed a wear reduction factor of 10 when, in addition to the phosphorus compounds, 1% of oleic acid was added. Factors as high as 17 have been found with other combinations.

Female Woodcock on nest: easy to photograph, not easily distinguished.
—W. Bryant Tyrrell

Hatching TOMORROW'S POSSIBILITIES

Powder metallurgy has been in a process of quiet incubation for a good many years . . . "protectively colored" from general observation. To be seen, of course, were some of its evidences: the tungsten lamp filament; diamond impregnated grinding wheels; porous metal bearings — among others. Now, suddenly it seems, there emerges a great awareness of powder metallurgy's promise as a method for making many metal parts and materials.

Need for replacement materials has helped intensify interest in Powder Metallurgy's new and larger role. Metals Disintegrating Company, manufacturer of all kinds of metal powders through 25 years, is making new materials practical to use. Iron powder, for example: pistons of powdered iron are now replacing aluminum pistons in hydraulic brakes.

Our unique experience in this field has proved helpful to many a manufacturer with a powder application "hen on the nest." That experience of a quarter century—and familiarity with current developments in materials and equipment and processes—will be available to manufacturers seeking new advantages in *tomorrow's* markets.

METALS DISINTEGRATING COMPANY
ELIZABETH NEW JERSEY

METAL POWDERS SINCE 1916

INCLUSIONS IN HIGH SULPHUR STEEL*

By E. Gregory and J. H. Whiteley

A STEEL INGOT containing 0.40 to 0.50% sulphur was examined for heterogeneity and type of inclusions. In making the ingot most of the sulphur was added as pyrite in two stages to the basic openhearth furnace, with final adjustments made by adding "rock" sulphur to the ladle. The tapping slag contained 19.4% Fe and 9.82% P_2O_5. The selected ingot weighed 5150 lb. and was teemed into a big-end-up mold. After sectioning down the middle, the surface of one half of the ingot was prepared for sulphur printing and then for macro-etching; the other half was cut up for micro-examination and chemical analysis at the "standard" positions laid down by the Ingots Committee.

The sulphur print shows no greater relative degree of segregation in regard to sulphur than in a steel regarded as having a "normal" sulphur content (say, 0.050% S). The excellent photograph shown in the original may therefore be regarded as a picture of its distribution in any commercial steel ingot except an electric furnace steel. In other words, the mechanism of segregation seems to be about the same in both high and low sulphur steels.

In the ingot examined, the elements which tend to segregate to the least extent are carbon, manganese, phosphorus and nitrogen; the greatest variation is in sulphur, oxygen and hydrogen, which segregate, but independently. Chemical analysis and microscopic examination indicate some inverse segregation of sulphur and oxygen. (High sulphur is accompanied by a relatively low oxygen, and vice versa.) Evidently sulphur, as well as manganese, plays an important part in the ultimate degree of deoxidation.

With a low oxygen content the larger inclusions are homogeneous but with higher oxygen content their structures are duplex in nature. Three test pieces all contained many round dove-gray inclusions of various sizes — mostly MnS with FeS, the amount of FeS being greater in the highly segregated areas. In fact, no FeS was found in the comparatively homogeneous

(Continued on page 826)

*Abstract of "Examination of a High Sulphur, Free-Cutting Steel Ingot", paper for British Iron and Steel Institute, June 1941.

HIGH S STEEL

(Continued from page 818)

parts. Whether the presence of FeS inclusions was due to the lack of Mn in the area was investigated by studying the migration of manganese in steel at different temperatures up to 2450° F. The indicators used were the retarding action of manganese on pearlitic coalescence and the conversion of FeS to MnS. Diffusion is slow but increases with temperature. The inference that the persistance of FeS in the heavy segregate was due to a very slow movement of the manganese in the steel certainly seems plausible.

Tests verified that a large proportion of the sulphide had existed as FeS in the ingot during solidification, and that coalescence of sulphides continued to a temperature well below that at which MnS becomes fixed in size. The appreciable growth of the FeS inclusions at 1850° F. — well below their melting point — affords strong evidence of the solid solution of this compound in iron. MnS is at most but slightly soluble in steel up to 2300° F.

The distribution of small sulphide particles in remelted areas and their size range suggested that they were the residues of binary and ternary eutectics. In this case the eutectic constituents certainly did not include iron, for the eutectic of the Fe-FeS system contains about 85% of FeS and freezes at 1800° F., whereas the primary formation was already present in a piece quenched from 2650° F. The temperature at which the secondary formation appeared was also well above 2350° F.

Because of the occurrence of FeS in the segregate, severe cracking of the very high sulphur ingots might be expected. Yet very little trouble of that kind is experienced either in casting or in rolling the very high sulphur steel under examination.

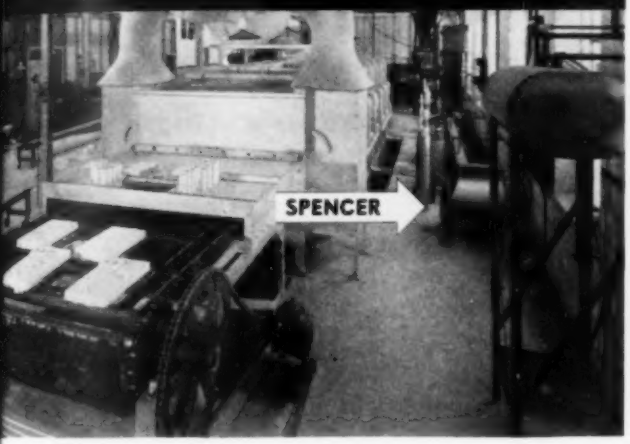
The cracking of ingots may be affected by the casting conditions. Thus HULTGREN demonstrated that after-pouring disturbed the columnar crystallization in ingots to within a short distance of the base. Thus, in top-filling, the stream from the nozzle can penetrate far down into the mold, even when it is almost full.

HALL has shown that, at temperatures just below the solidus, steels are not only very weak but have little or no elongation. Hence, when the ingot begins to solidify, the contraction stresses acting against the ferrostatic pressure may easily cause the early rupture noted by McCANCE. If a break occurs early, liquid metal may flow outwards and heal the rupture, but if it starts

(Continued on page 834)

Above: Car-type, recirculating oven. Core load 3600 lbs. THE PAUL MAEHLER COMPANY

Below: Mold oven. CONTINENTAL INDUSTRIAL ENGINEERS, INC.



3600 pounds of cores could hold up the production of a tremendous tonnage of castings if they weren't baked properly. The oven at the left is only one of hundreds of gas- and oil-fired equipments that are serving this bottle neck of the foundry industry faithfully year after year.

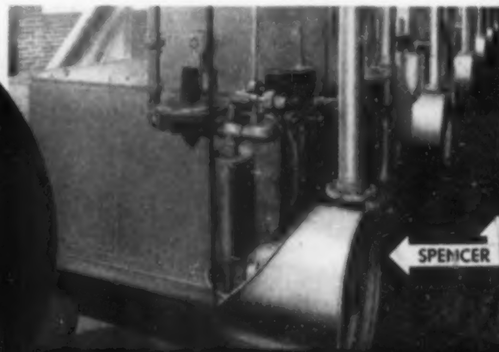
In order to insure the air supply on the ovens illustrated, these manufacturers chose Spencer Turbos—the kind that has been used on Foundry Cupolas for years.

Spencer Turbo-Compressors deliver a constant pressure with power input in direct proportion to the volume of air delivered. Wide clearances, only two bearings, and a highly efficient centrifugal impeller design are other reasons why the great majority of furnace and oven manufacturers prefer Spencer.

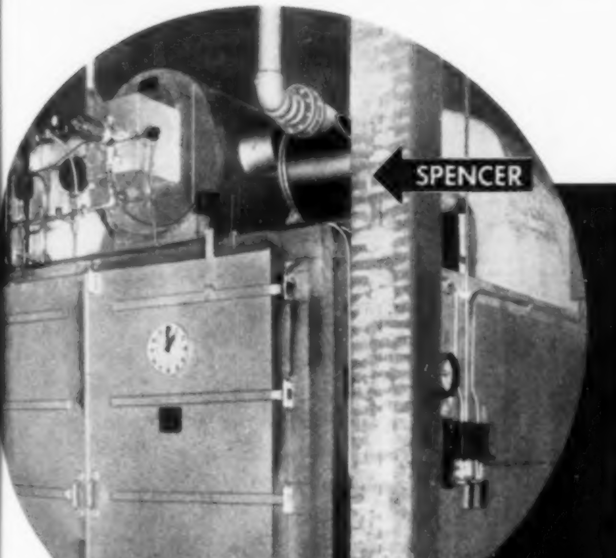
ASK YOUR EQUIPMENT MANUFACTURER FOR THE SPENCER TURBO BULLETINS

S-209-G

BAKING Cores and Molds



Core and mold ovens, car-type. FOUNDRY EQUIPMENT CO.



Baking cores in foundry. DESPATCH OVEN COMPANY

Three Spencer Turbos mounted on portable trucks on a Hauck equipped fire-brick kiln job. HAUCK MANUFACTURING CO.

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Combustion
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Gas Boosters
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35 to 20,000 cu. ft.
$\frac{1}{3}$ to 300 H.P.
8 oz. to 5 lbs.

THE SPENCER TURBINE COMPANY • HARTFORD, CONNECTICUT

HIGH S STEEL

(Starts on page 818)

a little later, the liquid within may not be reached and the crack will consequently tend to deepen as cooling proceeds.

If in freezing the skin forms gradually from the base upwards, producing a taper, the extent and suddenness of the overall contraction stresses will be lessened. Also the lower part of the shell will be better able to withstand them. This may be the reason that tun-dishing and the up-running methods of casting minimize cracking. As the liquidus-solidus range is widened (an effect of large amounts of FeS) a similar effect seems to arise from the longer presence in the skin of liquid layers normal to the surface. This may explain why virtually solid top-filled low carbon steel ingots very high in sulphur do not, as a rule, crack seriously as might be expected. Comparatively small quantities of FeS merely tend to form the fine intergranular liquid films which are believed to cause red shortness.

Besides the sulphides there was another type of inclusion found in this ingot. It was composed of globules, sometimes very large and often complex in structure. Within them were usually rounded MnS particles and an occasional idiomorphic crystal resembling chromite. Frequently the globules also contained areas of FeO, this compound not being elsewhere observed. The ground-mass in which these inclusions were embedded was eutectiferous in character and translucent owing to a silicate component. Various tests indicated that it belonged to the system fayalite-rhodonite-FeS-MnS-FeO.

The types of inclusions and their probable natures are classified in the table above.

Inclusions Found in 0.45% S Ingot

Tentative Identification	Heat Tinted	Reaction to		
		HCl	H_2SO_4	HF
MnS	Light blue	Insoluble	Completely soluble	....
Silicate	Dark gray, no definite change	Nearly insoluble	Nearly insoluble	Strongly attacked
FeS	Indefinite	Probably insoluble	Not visible	....
Chromite	Very dark, no change	Insoluble	Insoluble	Unattacked
FeO with MnO	Darker blue than MnS	Completely soluble	....	....

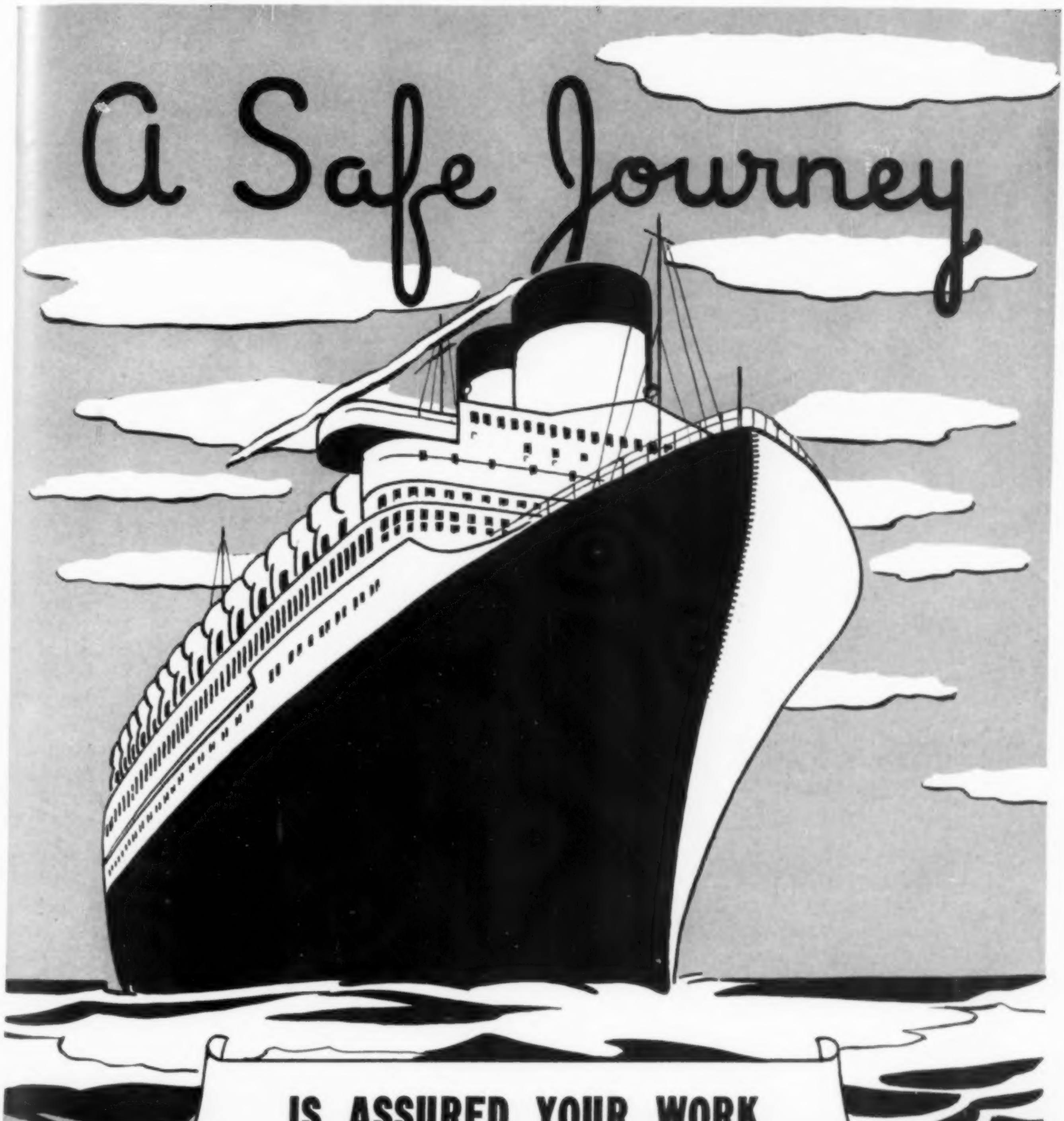
METAL POWDERS

(Continued from page 788)

of the same composition made by melting. The powder metallurgy bars were readily drawn into wire and possessed a coefficient of thermal expansion which made the material suitable for sealing into Corning 1-G type glass. The cast material used as comparison proved to be more coarse grained and brittle. In the discussion of the paper, it was pointed out that the high rate of oxidation of molybdenum at elevated temperatures did not permit the use of the material for resistors.

As this necessarily brief survey has suggested, the range of the conference, in both papers and discussion, was decidedly extensive and inclusive. Hence, it is fortunate that all the papers presented on this occasion, as well as those of last year's conference and some dozen others not given at either conference, are to be published as a book in the immediate future by the Amercian Society for Metals. Answers to queries brought up at the conferences will be included, so the book will accurately reflect the wide range of the meetings.

A second and even more important characteristic of the conference clearly marks this impending publication. This characteristic is of decided significance for the future of powder metallurgy and hence for the future of metallurgy as a whole. Throughout the conferences, a cordial generosity in the sharing of ideas and the free dissemination of knowledge derived from painstaking independent work has been most notable. This fact promises that the conference will continue to be a forum where artisan, engineer, and scientist, through common attack on common problems, contribute to the advantage of each other and of the group as a whole. Such cooperativeness is most necessary, indeed, when we look at the amazing rate at which powder metallurgy is developing. New products which cannot be made otherwise are still the mainstay of this branch of metallurgy, yet many have already won the courage to compete with products customarily made by machining. Advancing steadily in the development of new knowledge and continuing to share that knowledge openly with each other, powder metallurgists thus may look forward to making their joint undertaking of constantly greater benefit and value to our whole economy.


A Safe Journey
IS ASSURED YOUR WORK
WHEN PLACED IN OUR CARE
A. L. BROWN

SHELL

(Continued from page 784)

It must be remembered that shell must be made in real mass production; 700,000 anti-aircraft shell were fired in a single day during the Battle of Britain.

So much for the suitable metal. Forging *appears* to be easy. All that is necessary is to get a billet of correct size, heat it and then punch and draw. But try and do it so that the hole is concentric and smooth enough so boring will be unnecessary. Uniformly and thoroughly heated billets are the first necessity; rigid tool guides and work holders are the second. The mandrels on which the big caliber shells are drawn must be given especial attention. Quoted tool costs vary widely, from 38¢ to \$2.00 per shell, and reflect the different equipment and its maintenance, shop to shop. Since there is such a wide variation in the chromium and tungsten content of the toolsteels recommended for a given duty — say, the punch, or the gripper die — a substantial demand appeared for a recommended practice to cover the toolsteel, its heat treatment, the coolant, and the lubricant. (See Metal Progress last month, page 453, for a detailed description of forge shop methods, not only using presses and draw benches, but also forging machines.)

No *best* way is yet known for machining shell. Rather than wait for such a method to be discovered, one must go ahead immediately with the available tools and men. Despite the number of American shells "on order", it is shocking to find that little Canada is ahead of us right now in daily production. Of course, there's no reason why we shouldn't start looking for the best way to machine a 75-mm. H.E. shell — in fact, every reason why we should. Meanwhile, here are a few hints: Use magazine type of tool holders, assembled and adjusted in the tool room; they speed tool changes and enable the second-grade machinist to meet the tolerances. Likewise, it would probably represent an over-all economy to change tools after a fixed number of pieces, rather than wait for breakdown of cutting edge. Just now most of the machining troubles are laid to inferior or hard steel blanks — but such machine shop gripes are no news. The summarizer suggested that advantages in machining and heat treating might result if the medium caliber shell blanks could be lined up accurately and handled in pairs, base to base, to the last possible moment. Forging machines now produce two shell blanks from a single billet, and they are usually nipped apart immediately.